Application No. 09/909,488
APPEAL BRIEF
May 12, 2006

Patent
Attorney Docket: 33449.8029.US00

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re the Application of:

MURALIDHARA et al.

Serial No.: 09/909,488

Filed: July 20, 2001

For: NANOFILTRATION WATER-SOFTENING APPARATUS AND METHOD

Group Art Unit: 1723

Examiner: Fortuna, Ana M.

I hereby certify that this correspondence (along with any referred to as being attached or enclosed) is being deposited this 12th day of May, 2006 with the United States Postal Service as first class mail in an envelope addressed to Mail Stop Appeal Brief - Patents, Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.

Rena Iov

APPEAL BRIEF

Mail Stop Appeal Brief - Patents
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

A notice of appeal was filed on October 17, 2005.

[Continued on Next Page.]

Appeal Brief Under 37 C.F.R. § 41.37(c):

(i) Real Party-in-Interest

The real party-in-interest is Cargill, Inc., a Delaware corporation, 15407 McGinty Road West, Minneapolis, Minnesota 55440.

(ii) Related Appeals and Interferences

There are no related appeals or interferences.

(iii) Status of claims

Claims 31-35 and 37-39 are pending and are rejected. The rejection of claim 31-35 and 37-39 is appealed.

(iv) Status of Amendments

An amendment was filed January 24, 2006 in which claims 1 to 30, 36 and 40 were cancelled and claims 33 and 38 were amended. The amendment has been entered.

(v) Summary of Claimed Subject Matter

The appealed independent claim is claim 31. The content of claim 31 is described generally in Figs. 1 and 2 and at p. 6, ll. 7-13 and p. 14, ll. 1-9. Claim 31 generally describes a method for softening water having an input flow of potable water and passing at least 80 percent of the input flow through a nanofiltration element such that the output flow of permeate water has a hardness lower than that of the output flow of non-permeate water. The method includes use of a nanofiltration element configured to reject at least 80 percent of calcium ions from potable water. The method of claim 31 is particularly suited for in

home water softening where the input supply is potable water and the recovery must be greater than 80 percent such that the majority of the water passing through the system is softened for use and a minimal amount is output in the non-permeate waste stream.

(vi) Grounds of Rejection to be Reviewed on Appeal

In an advisory action mailed March 2, 2006, only the rejection over Nitya et al. is maintained. Thus the ground of rejection on appeal is whether claims 31-35 and 37-39 are patentable under 35 U.S.C. § 103(a) over Nitya et al.

(vi) Argument

Independent claim 31 (and dependent claims 32-35 and 38):

Nitya et al. is applied against claims 31-35 and 37-39 as showing "at least one NF" membrane module in a process for treating a source of potable water, e.g., municipal water, with a membrane having the claimed membrane rejection an operation properties, e.g. SR1 and NF90 membranes." (Advisory Action mailed March 2, 2006, p. 2.) Thus, "[o]ne skilled in that can expect the same results by operating the same membrane(s) for treating the same source at the same operating conditions, e.g., manufacturer suggested pressure ranges, pH conditions, and inherent membrane calcium and other salts rejection." (Id.) Further, "[r]egarding to the system or process high recovery, that can either be inherent of the membrane at the suggested pressure operation, or can be obtained by assembling multiple units in parallel, increasing pressure, or controlling the system operation in a known manner,

e.g. increasing pressure, controlling flow, etch. [sic]." (Office Action mailed August 15, 2005, p. 3.)

In summary, the rejection is premised on Nitya et al.'s alleged teaching of treating potable water with a nanofiltration membrane. The rejection further alleges that remaining elements of claim 31 are obvious as inherent or known to those skilled in the art with no supporting evidence. These elements include: "the nanofiltration filter element configured to reject at least 80 percent of calcium ions from potable water; receiving from the source of potable water an input flow of potable water having at least 2 grains of hardness per gallon; discharging a first output flow of permeate water comprising at least 80 percent of the input flow, and which has passed through the nanofiltration filter; and discharging a second output flow of non-permeate water comprising less than 20 percent of the input flow, and which has not passed through the nanofiltration filter; wherein the output flow of permeate water has a lower hardness than the output flow of non-permeate water."

Nitya et al., however, provide no motivation for one skilled in the art to investigate if nanofiltration could be used to soften potable water let alone that nanofiltration would work for that purpose, particularly at the conditions of 80 percent recovery as claimed. Nitya et al., a PowerPoint presentation entitled "Metropolitan Water District of Southern California, 1999-2000 HMC Clinic Presentation," relates to desalination of non-potable water to produce potable water through nanofiltration ("NF"), not the softening of potable water as claimed. Nitya et al. state that the goal of methods employed therein is "to reduce the cost of

the desalinating process." Nitya et al, Exhibit A, p. 2. Not surprisingly, desalination is defined by the Metropolitan Water District of Southern California ("MWD") as "[t]he process of removing salt from seawater or brackish water." MWD, *Glossary of Water Terms* (Evidence Appendix, Exhibit C, p. 4). Seawater or brackish water is not potable water. Thus, desalination refers to removal of salt from non-potable water to produce potable water, not the treatment of potable water. Nitya et al. equates desalination with total dissolved solids ("TDS") removal as follows: "[s]alination occurs when mineral salts dissolve and build up in a water source" and "[t]he metric associated with mineral salts is the amount of Total Dissolved Solids (TDS)." Nitya et al., Exhibit A, p. 2.

Nitya et al. provide no suggestion regarding the softening of potable water as claimed. Instead, Nitya et al. collect data related generally to water quality including total and free chlorine, turbidity, pH, SDI (silt density index), and TDS (individual components). Nitya et al., Exhibit A, p. 10. Nothing in Nitya et al. relates to softening. Further, Nitya et al. do not disclose the makeup of the input water used therein. However, based on the reference as a whole, the only reasonable inference that can be drawn about the input water is that it is brackish water formed when mineral salts dissolve and build up in a water source, and not potable water.

Independent claim 31 is not obvious in view of Nitya et al. because Nitya et al. does not disclose or suggest "receiving ... an input flow of potable water" as claimed in claim 31. Nitya et al. investigate the use of nanofiltration for desalination, *i.e.*, to produce potable

water from non-potable water. Nitya et al. do not teach or suggest to one skilled in the art a method of receiving "an input of potable water" and discharging an "output flow of permeate water [having] a lower hardness than the output flow of non-permeate water" under any operating conditions, let alone the operating conditions of claim 31.

Claim 31 further requires "discharging a first output flow of permeate water comprising at least 80 percent of the input flow, and which has passed through the nanofiltration filter." Nothing in Nitya et al., indicates or suggests that potable water can be softened with a nanofiltration membrane to a suitable level particularly when operated at a permeate recovery of 80 percent. Further, the Examiner provides no support for the assertion that a high recovery "can either be inherent of the membrane at the suggested pressure operation, or can be obtained by assembling multiple units in parallel, increasing pressure, or controlling the system operation in a known manner."

A permeate recovery of at least 80 percent is a specific operating condition of the method, not an inherent property of the membrane. A recovery of at least 80 percent is required by claim 31 when discharging an "output flow of permeate water [having] a lower hardness than the output flow of non-permeate water" because, contrary to the requirements for desalination processes as is the goal of Nitya et al., the current method is particularly suited for uses such as an in home use, where the input is potable water or uses requiring that the amount of non-permeate water be minimized thus minimizing any waste stream from the method. No reference or evidence has been cited that would indicate to one skilled in the art

that claimed ion rejection rates could be obtained when operating at the claimed recovery rate in treating potable water.

Nitya et al. do teach ion rejection by charge and by ion size for an NF200 membrane when operated at 10 percent recovery and a pH of 8. Nitya et al., pp. 25, 26. One skilled in the art would not view this teaching as indicating or suggesting that the membrane would reject at least 80 percent calcium ions for an input of potable water when operated at 80 percent permeate recovery. Ion rejection is highly dependent on several parameters including recovery rate, input concentration of both the ion studied and other materials in the input stream, flow rate, and operating pressure. Nitya et al. do not provide any information regarding the input water and do not provide flow rates. Further, in Nitya et al. permeate recovery is 10 percent, which would not suggest to one skilled in the art that similar rejections could be achieved at 80 percent permeate recovery, particularly when no other critical experimental data is provided. This eight-fold difference is a clear indication of non-obviousness.

Nitya et al. provide no motivation for one skilled in the art to investigate if nanofiltration could be used to soften potable water let alone that nanofiltration would work for that purpose, particularly at the conditions of 80 percent recovery as claimed. Applicant accordingly requests that the rejections of claim 31 and claims 32-35 and 38, claims dependent on claim 31, be reversed.

Dependent claim 37:

Dependent claim 37 depends on claim 31 and further includes that "the output flow of permeate water contains greater than 90 percent of the input flow." A recovery of 90 percent is an operating condition, not an inherent property of a filter. Nitya et al. does not teach or suggest softening of potable water at any conditions, let alone where the recovery is 90 percent.

The teachings of Nitya et al. provide no motivation for one skilled in the art to investigate if nanofiltration could be used to soften potable water, let alone that nanofiltration would work for that purpose, particularly at the operating condition of 90 percent recovery as claimed. Applicant accordingly requests that the rejections of claim 37 be reversed.

Dependent claim 39:

Dependent claim 39 depend on claim 31 and further includes the element "an output stream of permeate water of 200 gallons or more per 24 hour period." The permeate water output is particularly suited for a home use, which requires about 200 gallons of softened water in a 24 hour period. Nitya et al. do not teach or suggest operating at such a condition or under such operating conditions that the input potable water can be softened particularly when operating at 80 percent recovery.

Applicant accordingly requests that the rejections of claim 39 be reversed.

Additional References:

In the Advisory mailed March 6, 2006, the reference Odem, Wilbert, *Nanofiltration of High Salinity Groundwater on the Hopi Reservation* (1995) ("Odem") is also cited. The

present claims are patentable over Odem for similar reasons to those set forth above with respect to Nitya et al. Specifically, Odem is directed to treatment of high salinity ground water and as such does not implicate the treatment of potable water. Odem discloses that the input water for its tests has a TDS of 1060 mg/L to 2180 mg/L with an average concentration of 1420.8 mg/L. Odem, p. 9, table 1. According to the EPA's National Secondary Drinking Water Standards, the maximum recommended level for TDS in drinking water is 500 mg/L. U.S. Environmental Protection Agency, *List of Drinking Water Contaminants & MCLs* (last visited May 11, 2006) <http://www.epa.gov/safewater/mcl.html> (Evidence Appendix, Exhibit D, p. 13). As such, Odem does not teach the softening of potable water.

Further, Odem discloses 10% recovery. Odem, p. 13. As set forth above with respect to Nitya et a., a teaching at 10% recovery does not teach or suggest to one skilled in the art that similar rejection rates can be achieved at 80% recovery as claimed in claim 31 or 90% recovery as claimed in claim 37.

Respectfully submitted,
Perkins Coie LLP

Date: May 12, 2006

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(viii) Claims Appendix

31. A method for softening water, the method comprising:
providing a source of potable water;
providing at least one nanofiltration filter element in fluid communication with the source of potable water, the nanofiltration filter element configured to reject at least 80 percent of calcium ions from potable water;
receiving from the source of potable water an input flow of potable water having at least 2 grains of hardness per gallon;
discharging a first output flow of permeate water comprising at least 80 percent of the input flow, and which has passed through the nanofiltration filter; and
discharging a second output flow of non-permeate water comprising less than 20 percent of the input flow, and which has not passed through the nanofiltration filter;
wherein the output flow of permeate water has a lower hardness than the output flow of non-permeate water.

32. The method for softening water of claim 31, wherein the nanofiltration filter element has an average pore size that substantially permits the passage of water and monovalent ions but substantially prevents the passage of divalent ions.

33. The method for softening water in accordance with claim 31, wherein the method does not substantially increase the total salt levels relative to the input flow of water.

34. The method for softening water in accordance with claim 31, wherein the input flow is provided at a pressure of less than 200 pounds per square inch.

35. The method for softening water in accordance with claim 31, wherein the input flow is provided at a pressure of 140 to 200 pounds per square inch.

37. The method for softening water in accordance with claim 31, wherein the output flow of permeate water contains greater than 90 percent of the input flow.

38. The method for softening water in accordance with claim 31, wherein the output flow of permeate water has a hardness below 2 grains per gallon.

39. The method for softening water in accordance with claim 31, wherein the method is configured and arranged to have an output stream of permeate water of 200 gallons or more per 24 hour period.

(ix) Evidence Appendix

Exhibit A: Chandran, Nitya, et al., *Metropolitan Water District of Southern California, 1999-2000 HMC Clinic Presentation* (August 15, 2000) (referred to herein as "Nitya et al.").

Exhibit B: Odem, Wilbert, *Nanofiltration of High Salinity Groundwater on the Hopi Reservation* (1995).

Exhibit C: Metropolitan Water District of Southern California, *Glossary of Water Terms* (last visited May 11, 2006) <http://www.mwdh20.com/mwdh2o/pages/yourwater/glossary/glossary01.html>.

Exhibit D: U.S. Environmental Protection Agency, *List of Drinking Water Contaminants & MCLs* (last visited May 11, 2006) <http://www.epa.gov/safewater/mcl.html>.

(x) Related Proceedings Appendix

None.

Metropolitan Water District of Southern California

1999-2000 HMC Clinic Presentation

DRIP

- Desalination Research and Innovation Partnership is intended to reduce cost of the desalinating process
- Salination occurs when mineral salts dissolve and build up in a water source
- The metric associated with these mineral salts is the amount of Total Dissolved Solids (TDS)
- Major innovation is use of low pressure, semi-permeable membranes to treat the water for TDS

TDS (Total Dissolved Solids)

- What is TDS?
  - Mineral salts introduced into the water mainly from the ground and waste water.
- What it does
  - Clogs and corrodes piping
  - Contaminates irrigation processes, reducing agricultural productivity
  - Affects taste, odor and appearance of water

Project Statement

- Test the filtration capabilities of newly developed fouling resistant nanofiltration and ultra low-pressure reverse osmosis membranes
- Use the results to describe the behavior of nanofiltration membranes

Filter Types

Attributes	Microfiltration	Ultrafiltration	Nanofiltration	Reverse Osmosis
Molecular Size Exclusion	0.1 to 0.2 Micron	0.01 Micron	1 Nanometer (or 0.001 Micron)	0.01 Nanometer (or 0.00001 Micron)
Primary Use	Partial Removal of Bacteria and Viruses	Partial Removal of Bacteria and Viruses	Removal of Bacteria, Viruses, TDS and Ions	Removal of Bacteria, Viruses, TDS and Ions
Typical Operating Pressures	10-25 psig	25-150 psig	75-200 psig	200-1000 psig
Pretreatment Necessary?	No	No	Yes	Yes

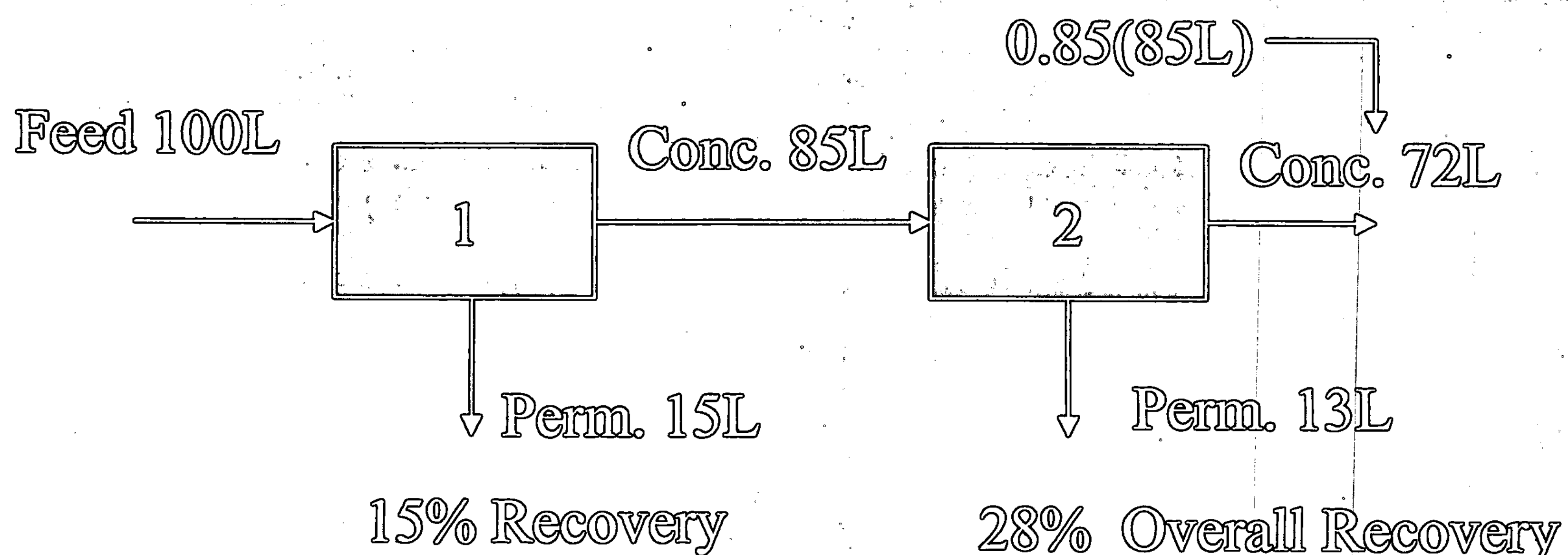
Test Matrix

Manufacturer	Model	Membrane Type	pH	Recovery (%)	Number of Runs
Hydranautics	CTC	NF	4.8, 6.5, AR	10, 50, 75, 90	12
Film Tec	NF90	RO	AR	10, 50, 75	3
Film Tec	NF200	NF	4.8, 6.5, AR	10, 50, 75, 90	12
Koch Fluid Systems	SR1	NF	AR	10, 85	2
Koch Fluid Systems	SR2	NF	AR	10, 85	2
Tri Sep	XN-40	NF	AR	10, 85	2
Tri Sep	TS-80	RO	AR	10, 85	2

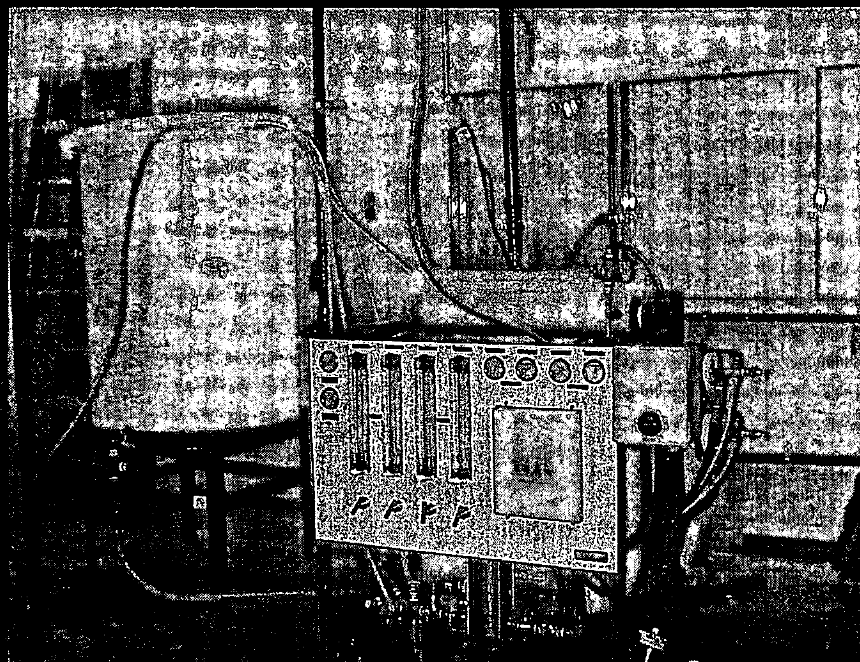
AR = As Received from Weymouth, at pH of about 7.5-8.1

Recovery

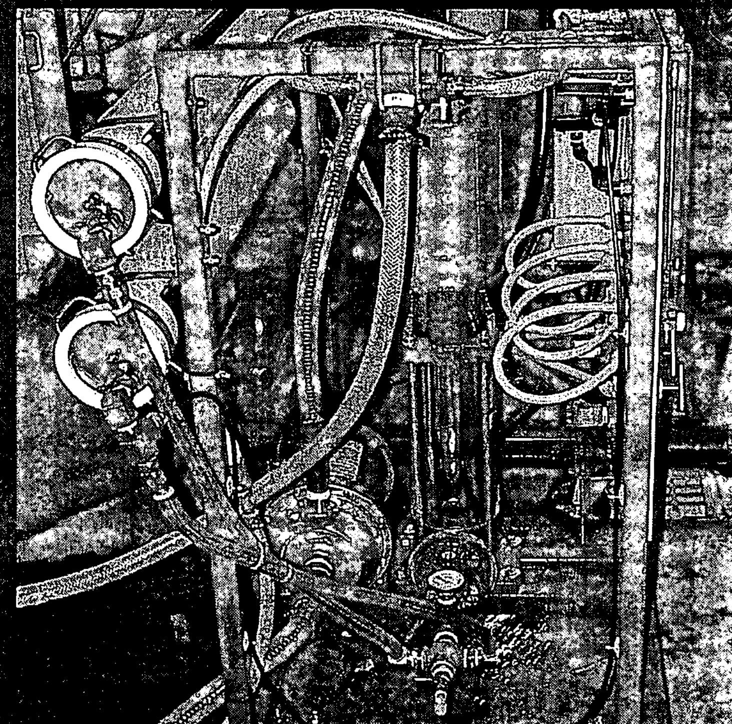
- Recovery is the percentage of the inlet water that exits the membrane as permeate



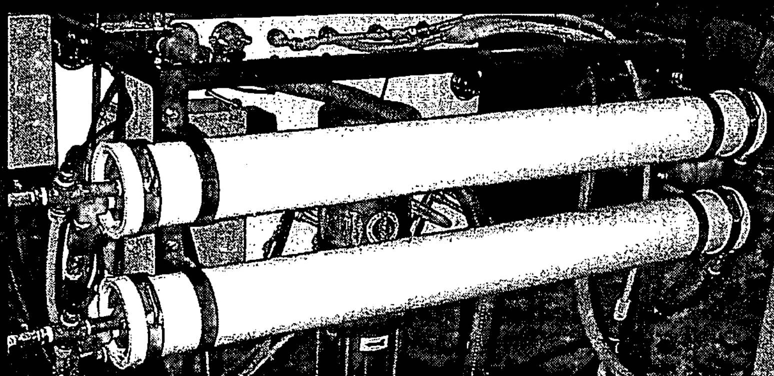
Test Equipment



Front View

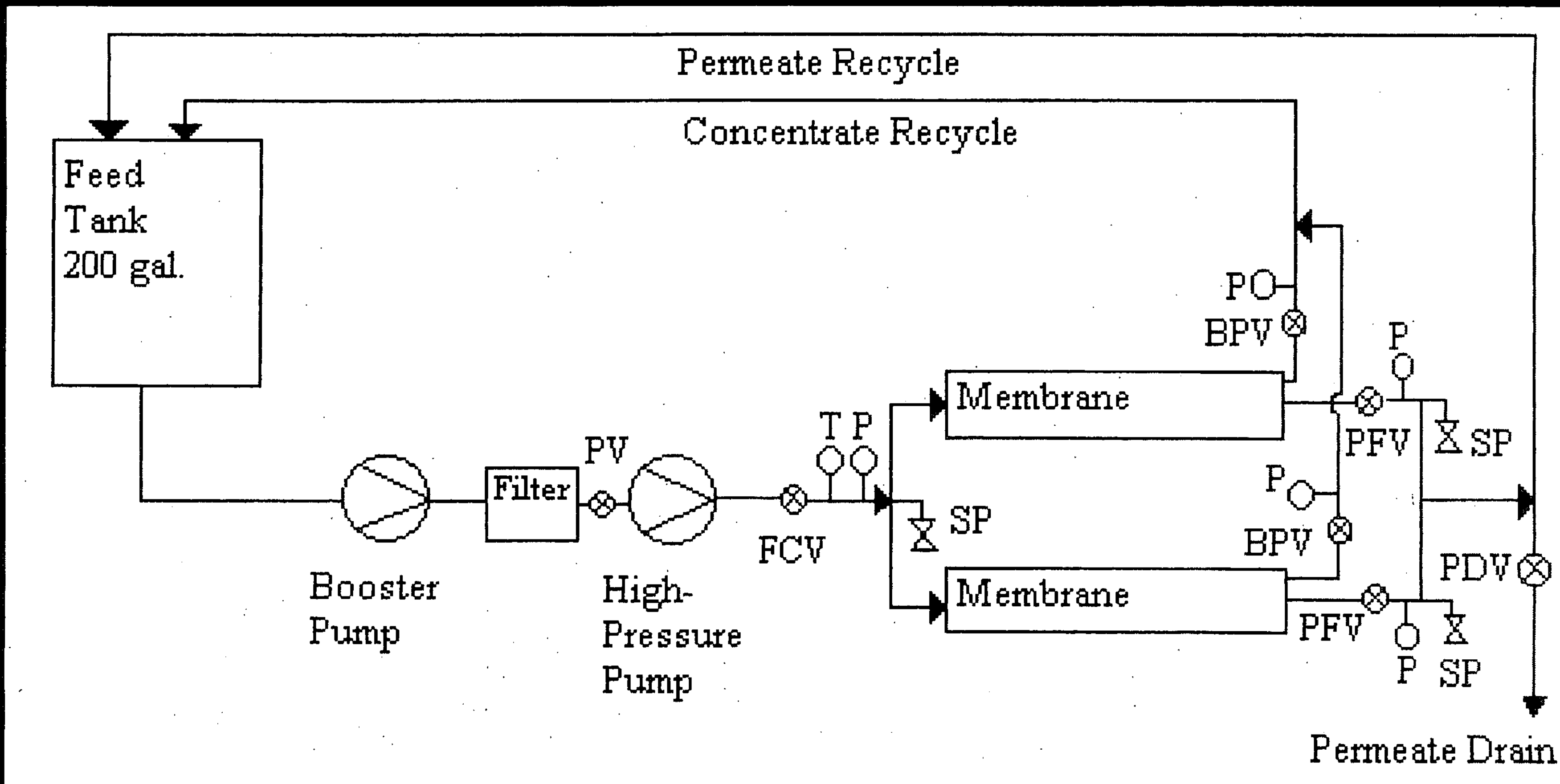


Side View



Back View

Flow Diagram



PV = Pressure Valve
T = Temperature Gage
SP = Sample Point
PFV = Permeate Flow Valve

FCV = Flow Control Valve
P = Pressure Gage
BPV = Back Pressure Valve

Data Collection

Typical test run 3-5 days

- Daily
  - Temperature
  - Flow Rate
  - Conductivity
  - Pressure
- Once per Test
  - Total and Free Chlorine
  - Turbidity
  - pH
  - SDI (Silt Density Index)
  - TDS (individual components)

Predicting Nanofilter Behavior

Metropolitan wants to predict how different nanofilters will perform under varying influent water conditions.

Modeling Approaches

- Microscopic
  - Base model on theoretical principles
  - Modify existing nanofiltration models
- Macroscopic
  - Base model on experimental results

Microscopic Modeling

- Basic Equations
  - Material Balances
  - Darcy's Law: $J=\Delta p/(\mu R_m)$
- Previously Developed Models
  - Solution-Diffusion for reverse osmosis
  - Recent nanofiltration models

Limitations

- Existing Models
  - Membrane charge is not accounted for in current Solution-Diffusion model
  - Membrane parameters unavailable from manufacturer
  - New nanofiltration models contain many variables involving membrane parameters, and are often specific only to one membrane

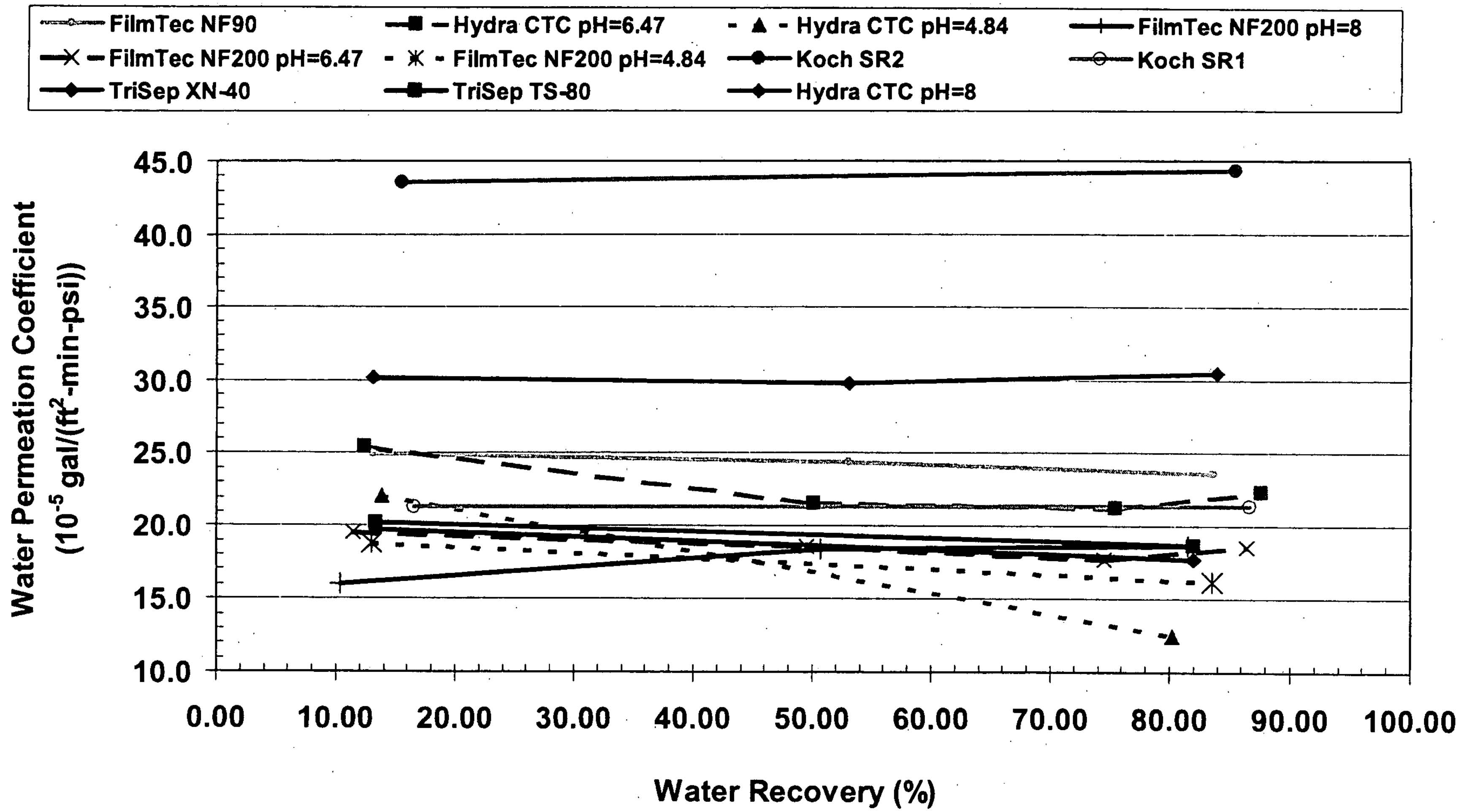
Macroscopic Modeling

- Direct observation of data
  - Note how nanofiltration membranes operate under different conditions
- Summarize and Interpret experimental results
  - Used fundamental equations to normalize data
  - Summarize observations based on trends observed

Test Results

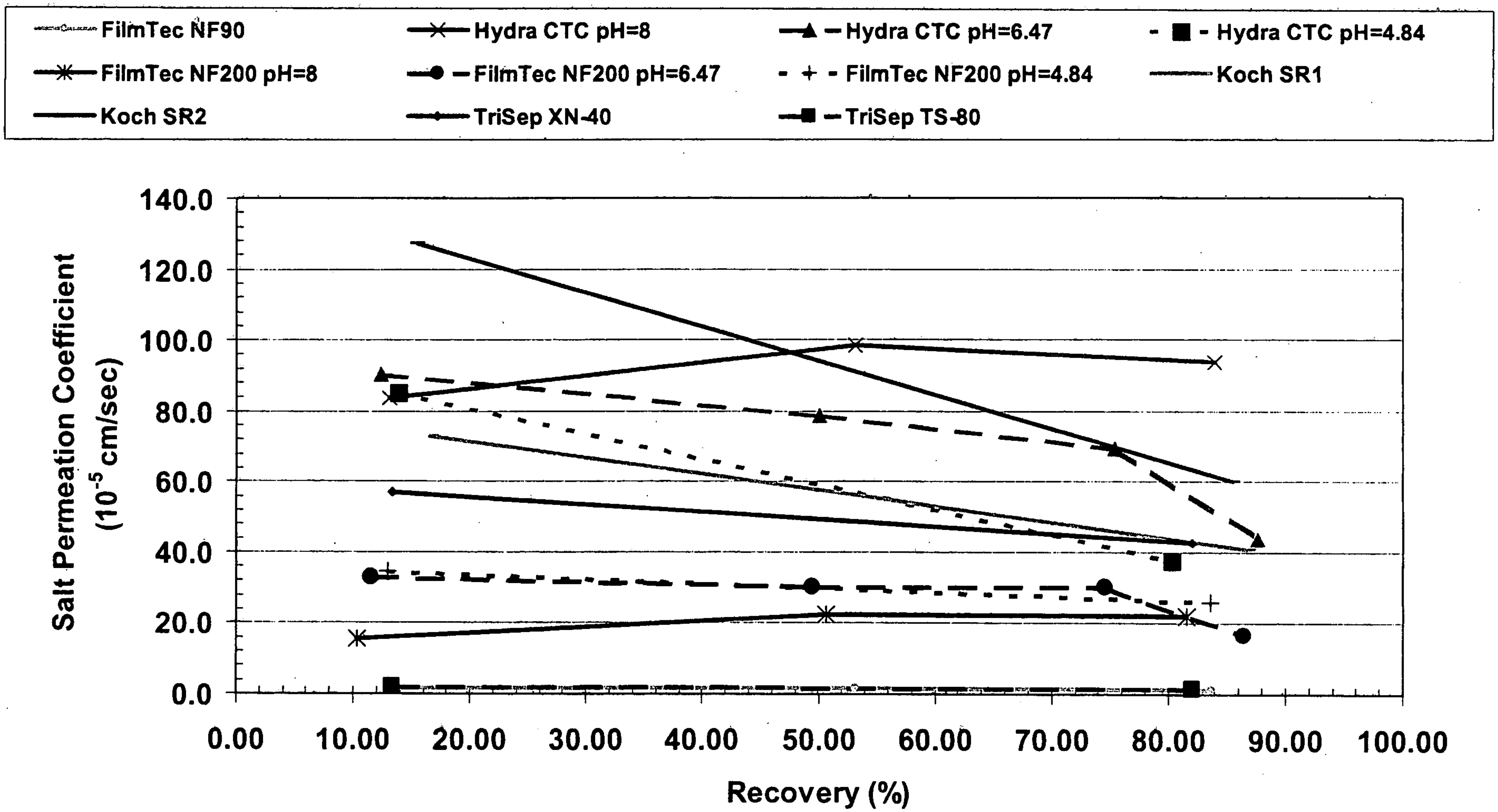
- Effect of recovery on membranes
- Effect of pH on two different membranes
- Effect of ion charge on membrane rejection
- Effect of ion size on membrane rejection
- Anion, Cation and Metal rejection

Performance of Nanofiltration Membranes for Surface Water Desalting



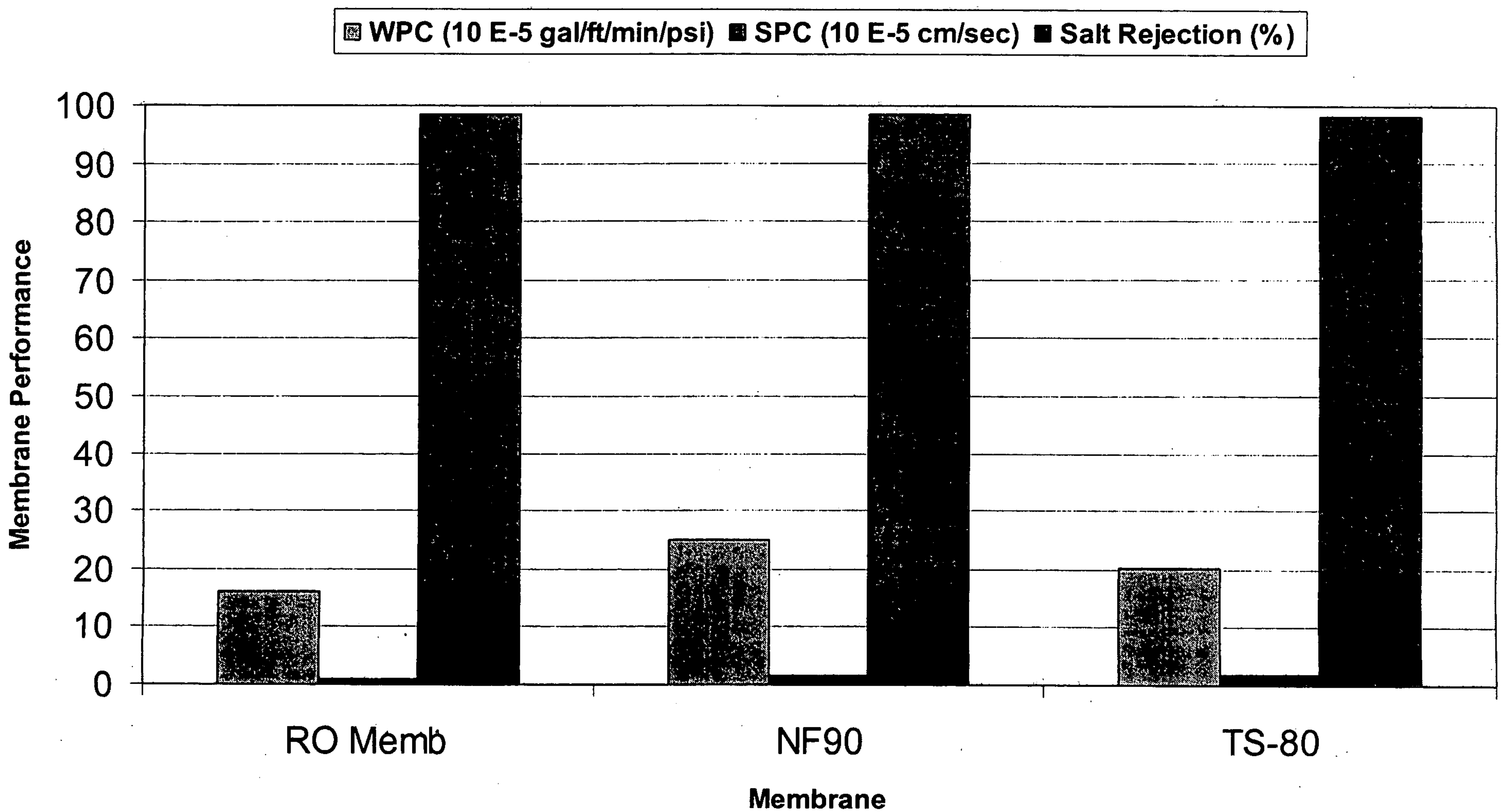
- The higher the Water Permeation Coefficient the better
- The lines should be flat

Performance of NF Membranes

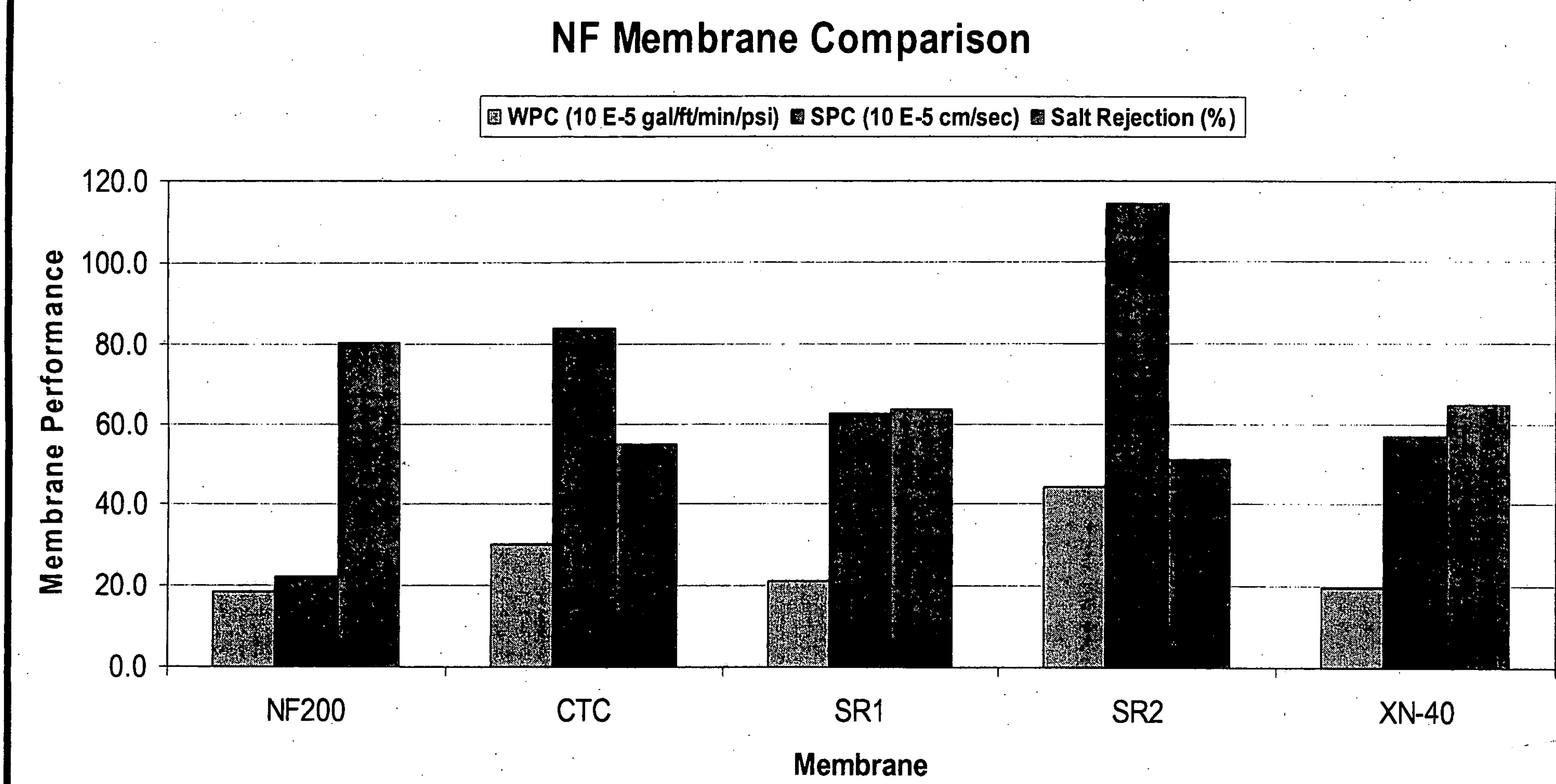


- The lower the Salt Permeation Coefficient the better (less salt passes through the membrane)

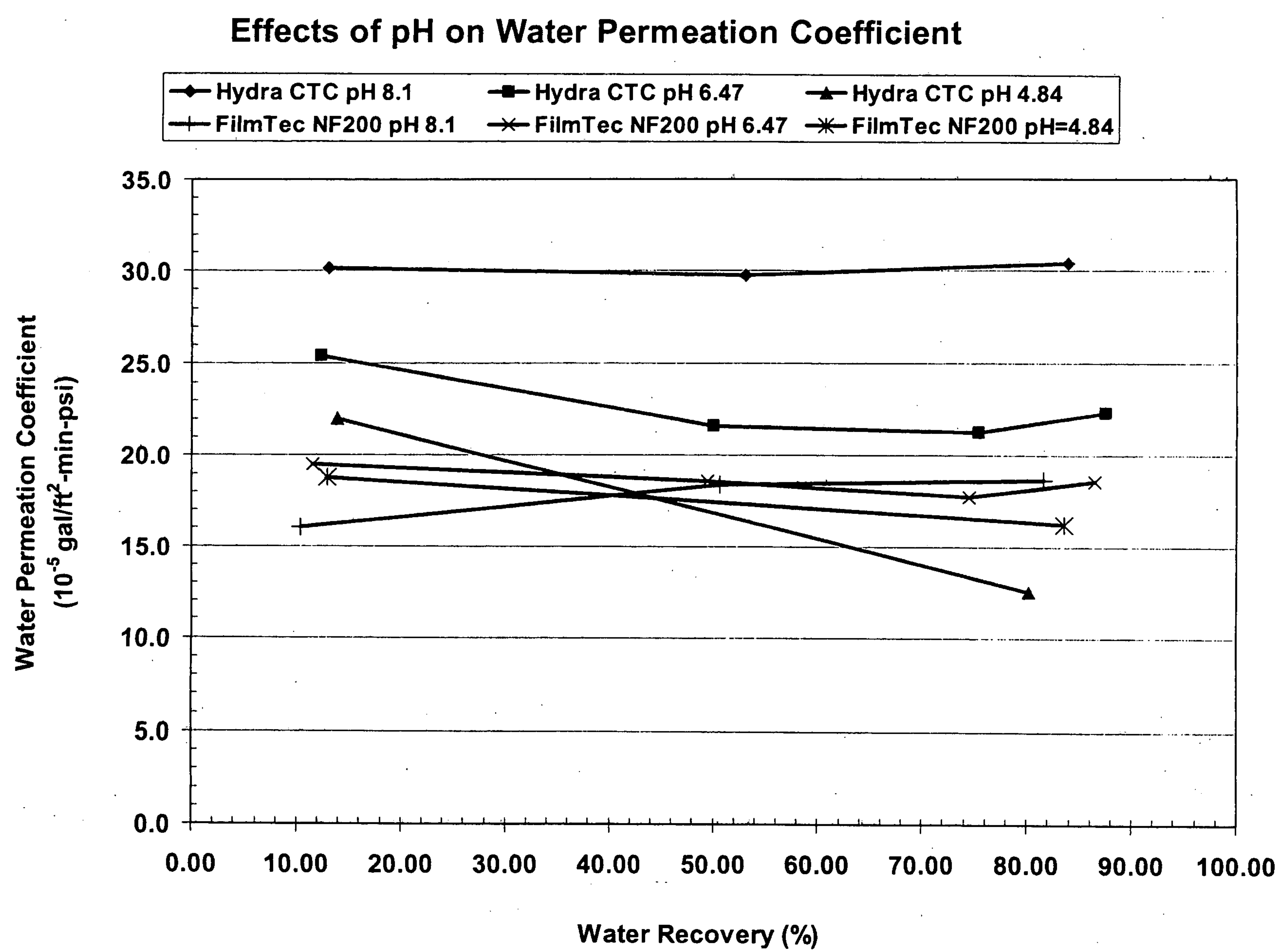
Comparison of Membranes To ULP RO Membrane

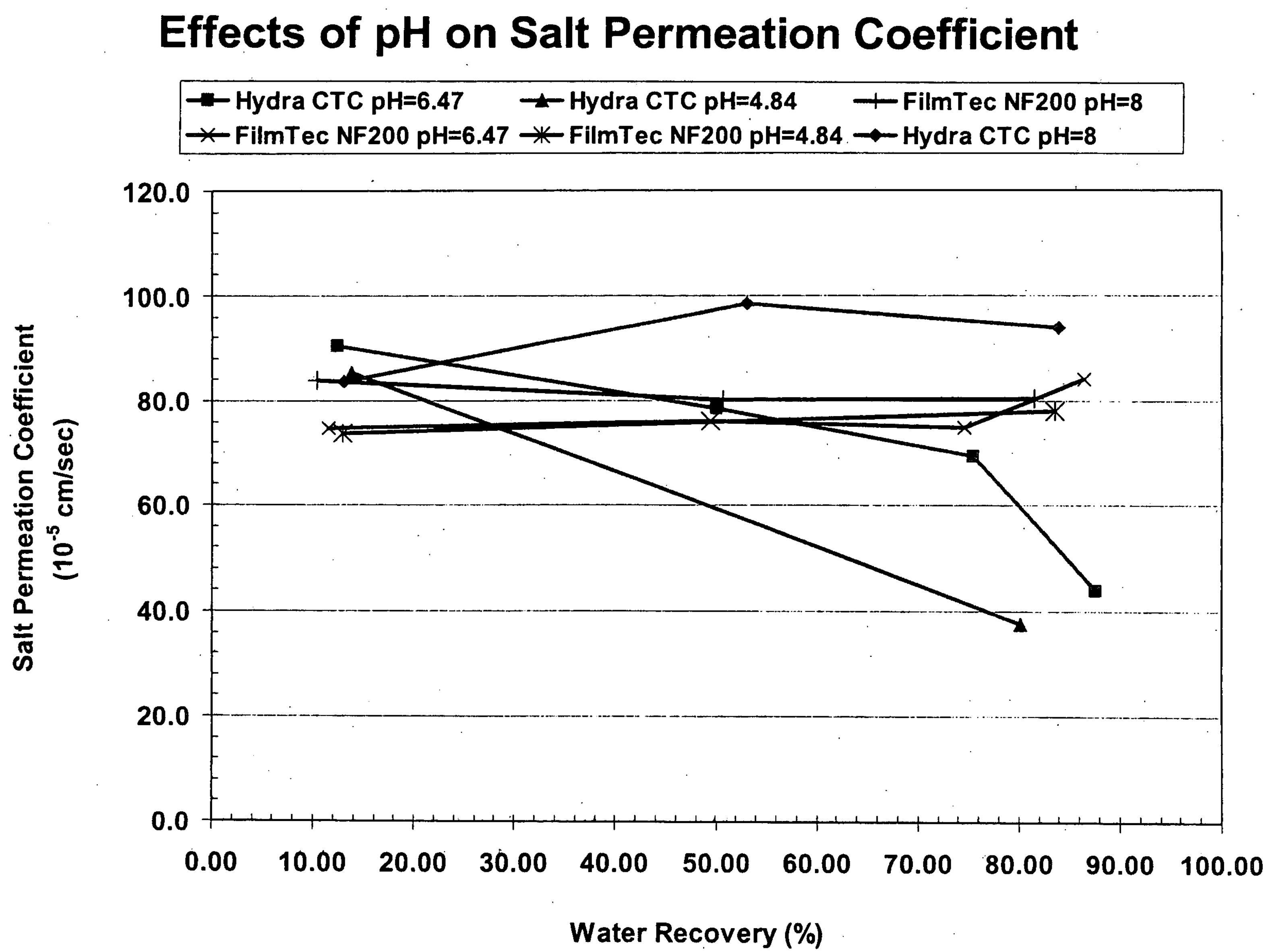


- The NF90 and TS-80 act like ultra low pressure RO membranes

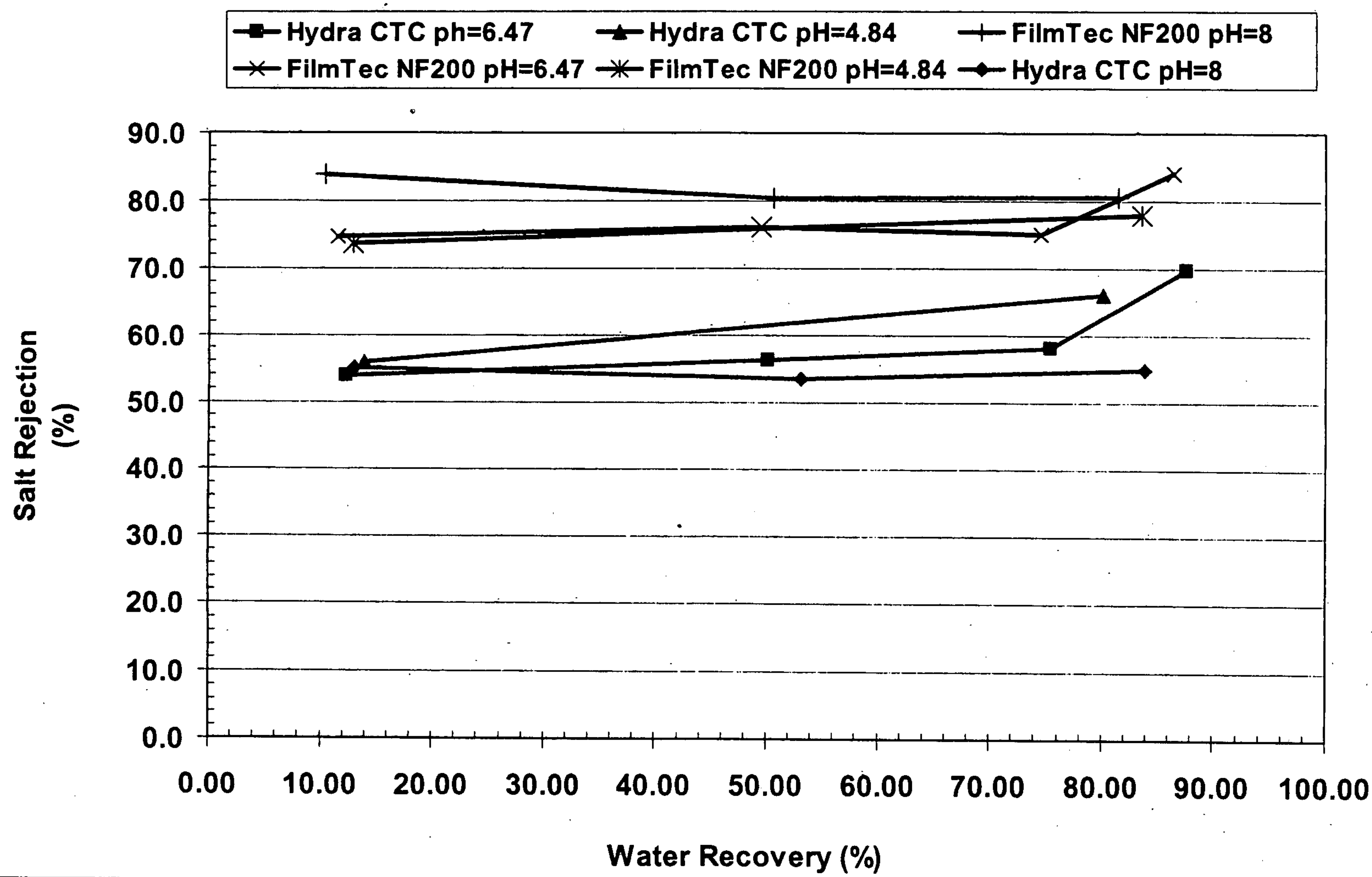


- NF membranes vary in performance due to the wide range of pore sizes

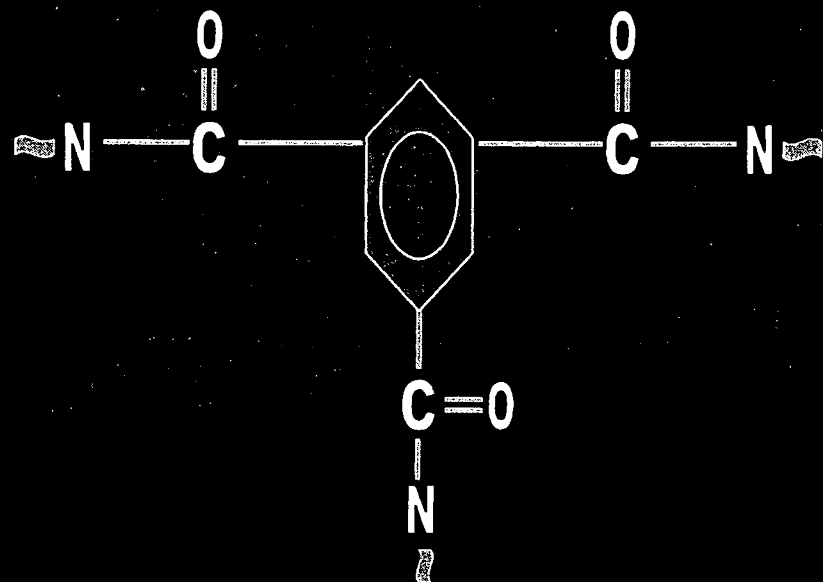

Effects of pH on Water Permeation Coefficient
Hydra CTC pH 8.1
Hydra CTC pH 6.47
Hydra CTC pH 4.84
FilmTec NF200 pH 8.1
FilmTec NF200 pH 6.47
FilmTec NF200 pH=4.84
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
Water Permeation Coefficient
(10^-5 gal/ft^2-min-psi)
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
90.00
100.00
Water Recovery (%)


Effects of pH on Salt Permeation Coefficient
Hydra CTC pH=6.47
Hydra CTC pH=4.84
FilmTec NF200 pH=8
FilmTec NF200 pH=6.47
FilmTec NF200 pH=4.84
Hydra CTC pH=8
Salt Permeation Coefficient
(10^{-5} cm/sec)
120.0
100.0
80.0
60.0
40.0
20.0
0.0
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
90.00
100.00
Water Recovery (%)

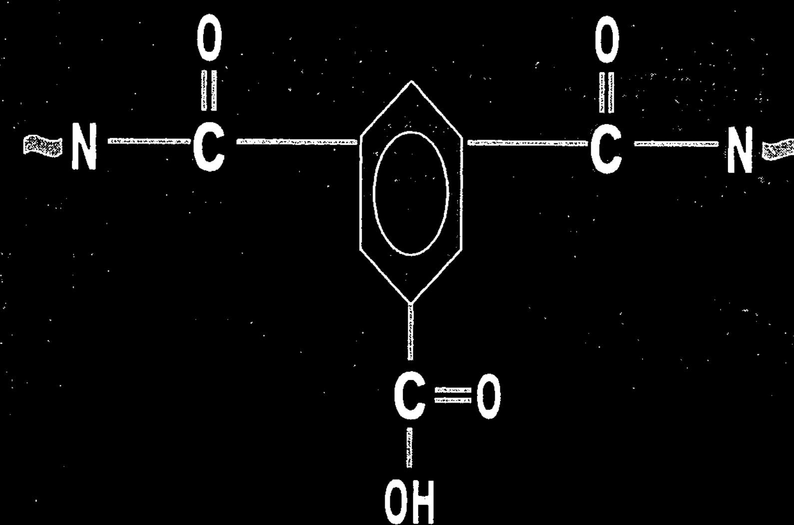
Effect of pH on the Performance of Nanofiltration Membranes

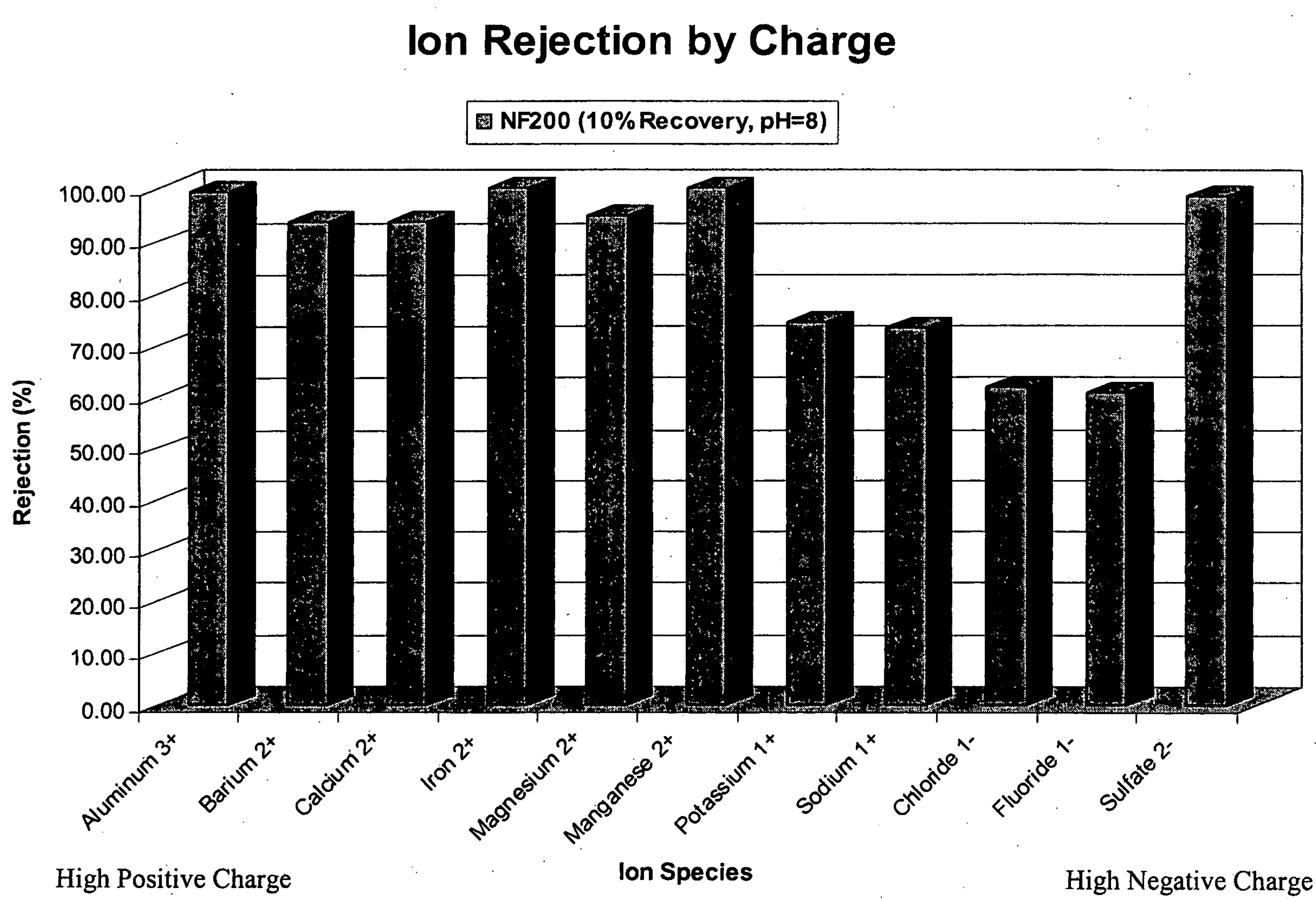


RO Lattice

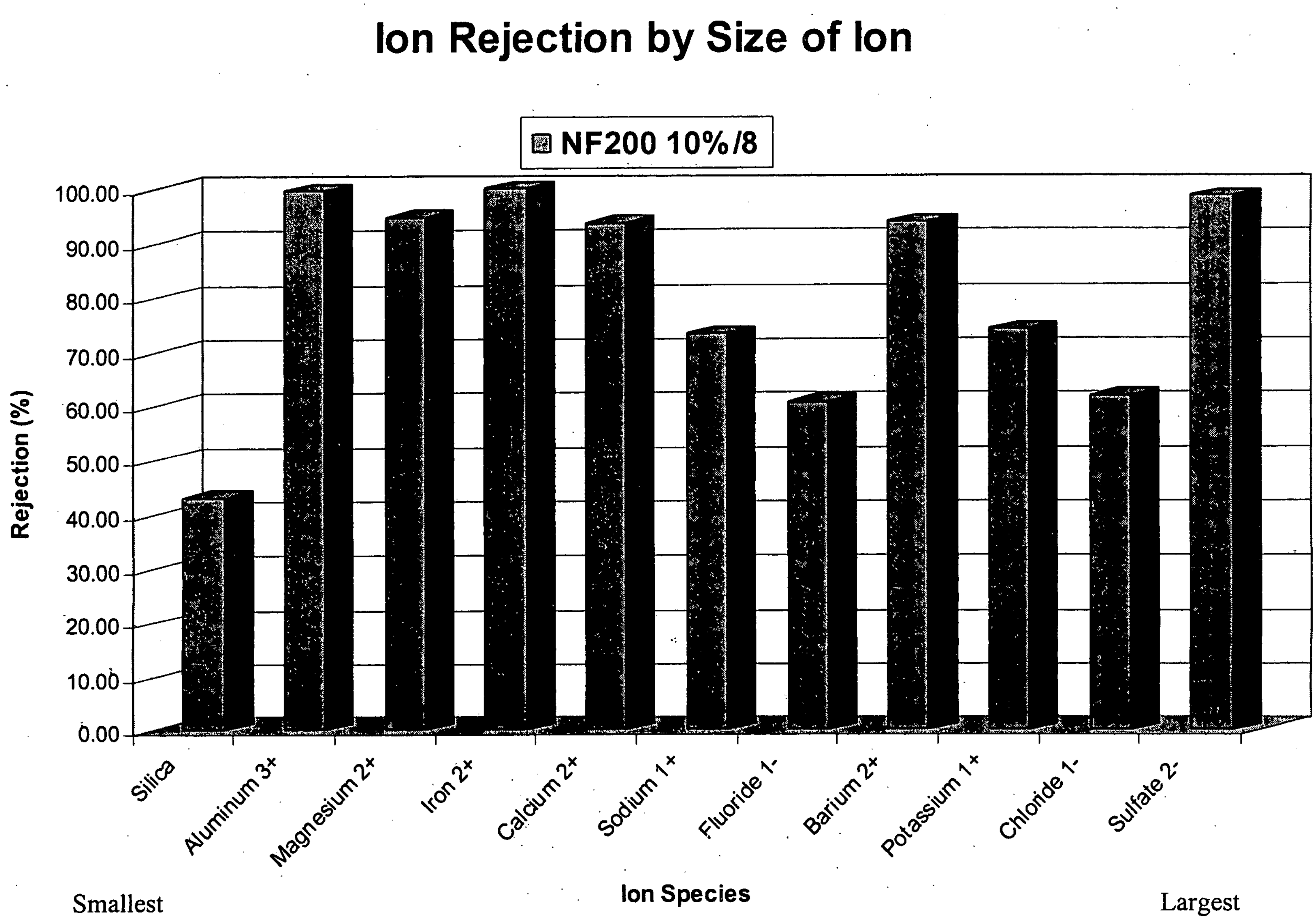


NF Lattice





- Each NF membrane follows this trend
- The rejection drops off when the ions have a lower charge



- Typical graph for NF membranes
- Size of ions is not basis for rejection
- Some ions that cause scaling can pass through NF membranes

Summary of Results

- Water permeation coefficient is relatively independent of recovery
- The effect of pH varies by membrane and by recovery
- The charge of the ions seems to have more impact on the rejection than the size of the ions

Team Members

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  - Dr. Craig Bartels

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- Milton Cox
- Connie Chou

NANOFILTRATION OF A HIGH SALINITY

GROUNDWATER ON THE

HOPI RESERVATION

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Contract No. 1425-3-CR-81-19540

Water Treatment Technology Program Report No. 3

May 1995

U. S. DEPARTMENT OF THE INTERIOR
Bureau of Reclamation
Denver Office
Technical Services Center
Environmental Resources Team
Water Treatment Engineering and Research Group

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12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

Commercial nanofiltration membranes were evaluated using a pilot scale testing apparatus for treatment of a high salinity groundwater used as a drinking water source at the Hopi Junior/Senior High School. Based on short term testing results (pressure requirements and permeate quality) two of the membranes were selected for longer term testing in the laboratory and on-site. Both of these membranes provide satisfactory treatment results which indicate that in a full scale system either membrane would produce drinking water that meets Federal and State requirements for total dissolved solids.

14. SUBJECT TERMS
Nanofiltration/drinking water/salinity/"N" Aquifer/Hopi Tribe water resources

15. NUMBER OF PAGES
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16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRAC
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NANOFILTRATION OF A HIGH SALINITY

GROUNDWATER ON THE

HOPI RESERVATION

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Northern Arizona University
Flagstaff, AZ

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U. S. DEPARTMENT OF THE INTERIOR
Bureau of Reclamation
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Water Treatment Engineering and Research Group

Bureau of Reclamation
Mission Statement

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

U.S. Department of the Interior
Mission Statement

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally-owned public lands and natural resources. This includes fostering sound use of our land and water resources; protecting our fish, wildlife, and biological diversity; preserving the environmental and cultural values of our national parks and historical places; and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all people by encouraging stewardship and citizen participation in their care. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. Administration.

ACKNOWLEDGEMENTS

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GLOSSARY

ACRONYMS/ABBREVIATIONS

an	centimeters
DBSA	Daniel B. Stephens and Associates
MCL.	maximum contaminant level
N	Newtons
NF	nanofiltration
ntu	nephelometric turbidity unit
O&M	operations and maintenance
psi	pounds per square inch
RO	reverse osmosis
SDI	silt density index
SR	salt rejection
TDS	total dissolved solids
TOC	total organic carbon
uv	ultraviolet

CHEMICAL FORMULAS

Al^{3+}	aluminum ion
Ba^{2+}	barium
Ca^{2+}	calcium ion
$CaCO_3$	calcium carbonate
Cl^-	chloride ion
Cl_2	chlorine
Cr	chromium
Fe^{2+}	ferrous ion
Fe*	ferric ion
H^+	hydrogen ion
HCO_3^-	bicarbonate ion
H_2O	water
H_2SO_4	sulfuric acid
K^+	potassium ion
Mg^{2+}	magnesium ion
Mn^{2+}	manganese ion
Na^+	sodium ion
Ni	nickel
NO_3^-	nitrate ion
SiO_2	silica
SO_4^{2-}	sulfate ion

SUMMARY

Commercial nanofiltration membranes were evaluated using a pilot scale testing apparatus for treatment of a high salinity groundwater used as a drinking water source at the Hopi Junior/Senior High School. Based on short term testing results (pressure requirements and permeate quality) two of the membranes were selected for longer term testing in the laboratory and on-site. Both of these membranes provided satisfactory treatment results which indicate that in a full scale system either membrane would produce a drinking water which meets Federal and State standards for TDS.

Hopi Tribal officials have expressed interest in the results of this testing. This information will be used to help determine their response to the water quality problems at the school. Officials of the Bureau of Indian Affairs, which is responsible for facilities at the high school, also have expressed interest in the results.

Preliminary estimates for a full scale system indicate that the system costs, installation costs, and first year checkout and monitoring will cost approximately $ 125,000, or about $2.50 per installed gallon per day, based on a 50,000 gallon per day need. Operation and maintenance costs are estimated at approximately $0.95 per 1000 gallons. Assuming a 20-year project life, the total costs are approximately $1.29 per 1000 gallons.

1 .O INTRODUCTION

Included in the Bureau of Reclamation's Water Treatment Technology Program's objectives is the development of effective and economic treatment of impaired quality water for rural America. According to the Program Plan the program will emphasize 'substantial participation by the non-Federal desalting and water treatment communities and by academia'. The Program Plan also emphasizes the importance of technology transfer to communities that can benefit from information developed through Program-sponsored research.

1.1 Background

Three water supply wells at the Hopi Junior and Senior High School serve the needs of the school and of the adjoining teachers: community. The school is located approximately 7 miles (11.3 km) east of the town of Polacca on the Hopi Reservation, or about 150 miles (241.4 km) northeast of Flagstaff, Arizona (Figure 1). Approximately 500-600 students attend the school and approximately 150 residents live in the teachers' community. Additionally, the water is used for landscaping and fields maintenance at the school. The three wells feed into an elevated storage tank located behind the school. The water from these wells is high in TDS (total dissolved solids), with high concentrations of sodium, chloride, and sulfate. The water quality does not represent a health threat, but has presented problems due to objectionable taste and corrosion of pipes and water heaters, and has caused problems with maintenance of the school football field

Dulaney (1989) stated that the Navajo, or "N", Aquifer has two chemically distinct types of water: 1) a calcimn bicarbonate type of water found in the north and west portions of the aquifer system, and 2) a sodium-chloride-sulfate. type of water near the east and southeast of the aquifer system (where the high school wells are located). Dulaney suggested that the high salinity associated with the sodium-chloride-sulfate waters may be due to mixing with either the overlying "D" Aquifer or the underlying "C" Aquifer. A report by the Council of Energy Resource Tribes (1989) on water quality issues on the Hopi reservation presented mean water quality data for water from the "N" Aquifer, the "D" Aquifer, 'the "C" Aquifer, and the alluvial aquifer. Data from the high school wells more closely resembles mean water quality from the "D" Aquifer, a lower quality source than the "N" Aquifer. However, ranges of data show that the high school water chemistry falls within maximum values presented for the "N" Aquifer (CERT. 1989). Daniel B. Stephens & Associates (DBSA) compiled the Report of Year Two Activities EPA 106 Water Quality Assessment Program for the Hopi Tribe. In this report DBSA addressed the problem of high salinity in the three high school wells and one in the nearby community of Polacca. A summary of water and analyses for the three high school wells was presented and is shown in Table 1. Figure 2 shows a map of the "N" Aquifer on the Hopi and Navajo Reservations.

DBSA suggests two reasons for the lower quality "N" Aquifer water observed in these wells: 1) a natural mixing of waters from the "N" Aquifer and the "D" Aquifer due to either faulting in the area, or more likely, to the correlation of the high salinity wells with the south-southeast boundary of the "N" Aquifer, or, 2) mixing of waters from the two aquifers due to poor construction of the high school wells. DBSA identified four possible mitigation options for addressing natural or manmade degradation of "N" Aquifer water quality at the Hopi High School:

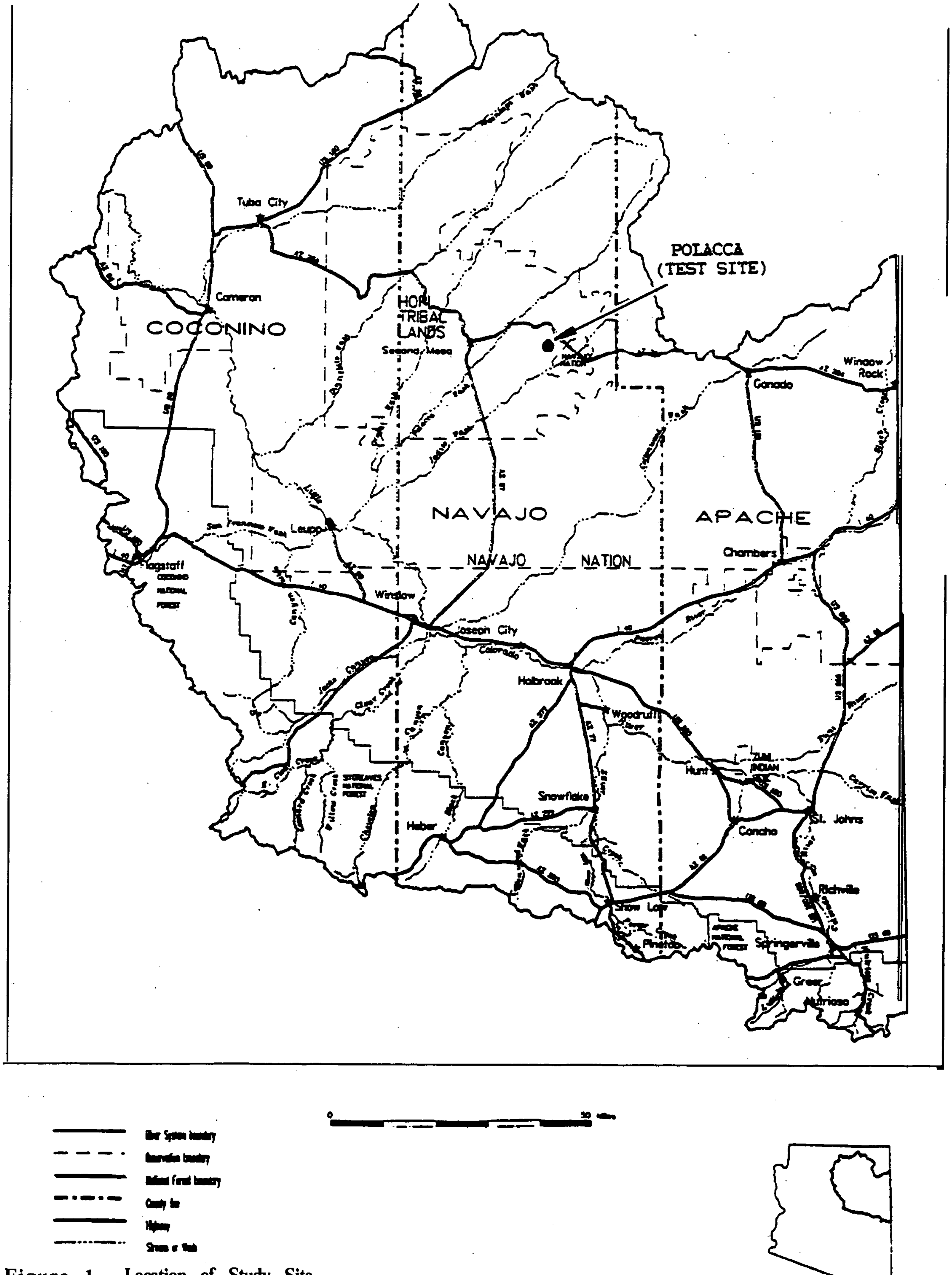


Figure 1. Location of Study Site.

TABLE 1. Water Quality of the Hopi High School Wells.

Parameter	Avg. Concentration (mg/l)	Concentration Range (mg/l)
Arsenic	< 0.02	
Barium	< 0.1	
cadmium	< 0.005	
Chromium	< 0.02	
Fluoride	2.58	
Lead	< 0.02	
Mercury	c 0.001	
Nitrate	0.14	
Selenium'	< 0.005	
Silver	< 0.02	
Alkalinity (as $CaCO_3$)	286.2	260 - 445
Calcium	4.88	1.4 - 8.0
Chloride	463.8	230 - 760
Copper	0.12	
Hardness	15.4	
Iron	0.2	
Magnesium	1.2	0.4 - 2.0
Manganese	< 0.05	
Potassium	1.62	0.8 - 2.8
PH	8.74	8.4 - 9.1
Silica (as SiO_2)	4.43	3.66 - 5.36
sodium	532.0	258 - 810
Sulfate	171.0	80 - 365
TDS	1420.8	1060 - 2180
Zinc	< 0.06	
E.C. (uS/cm)	2435	1550 - 3140

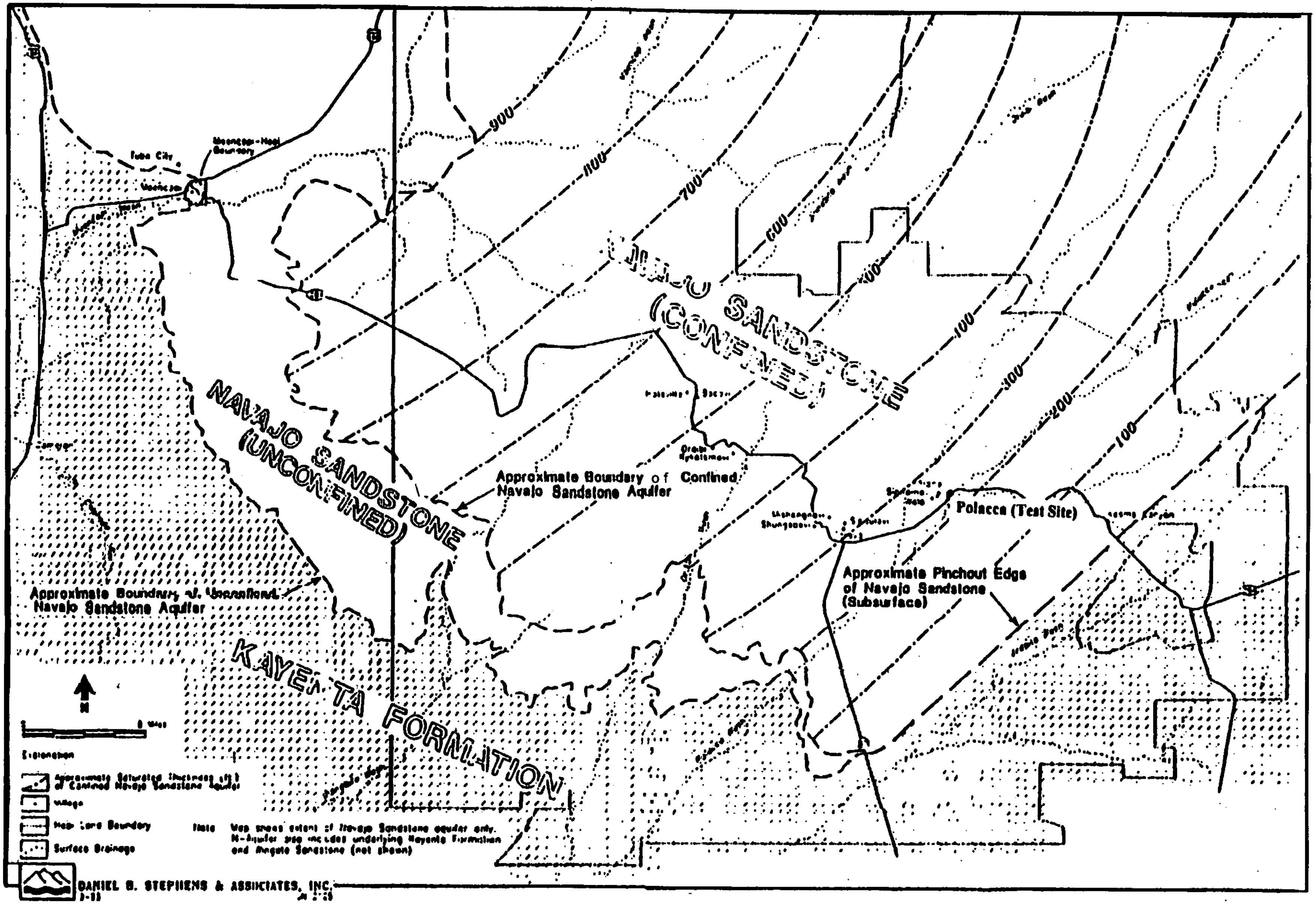


Figure 2. **Extent of Navajo ("N") Aquifer On The Hopi & Navajo Reservation.**

* Down-hole geophysical and water quality studies to attempt to identify the source of saline water,
* Rehabilitation of existing wells;
* Drilling of new wells;
* Installation of a water treatment (reverse osmosis type treatment system).

Down-hole testing has been completed for Well #3 with results inconclusive as to the amount of seepage that may be occurring from the "D" to the "N" Aquifer. At this time the Hopi Tribe is considering the three remaining options for mitigating the salinity problem.

1.2 Purpose of Study

The purpose of the present study is to investigate the technical feasibility of using nanofiltration to treat the water supplied by the three wells at the Hopi High School. This project was proposed in response to the Bureau of Reclamation's Request for Proposals for a preliminary research study of possible desalination demonstration projects under the Water Treatment Technology Program. A previous study by researchers at Northern Arizona University (Speidel, 1993) contained data that suggested that nanofiltration technology might provide a more cost-effective approach to treatment than reverse osmosis. Nanofiltration is typically used to remove chemical compounds greater than a molecular weight of 500 Daltons. The advantage it offers over reverse osmosis is lower operating pressures, less strict pretreatment requirements, and a less concentrated reject brine which may alleviate disposal problems. Continued progress in membrane development has produced commercially available membranes that approach reverse osmosis rejection capabilities, but operate at lower pressures typical for nanofiltration. This study identified and tested commercially available nanofiltration membranes for heating the groundwater supplied by the wells at the Hopi High School.

2.0 METHODOLOGY

2.1 Preliminary Work

Prior to the actual testing of the membranes initial work had to be performed as described in the following tasks:

* determination of source water quality;
* identification and acquisition of candidate membranes:
* construction of pilot-testing apparatus.

The membranes selected for evaluation were as follows:

FilmTec NF90
FilmTec NF45
Desalination Systems Desal-5
Desalination Systems DK
Hydranautics PVD 1
Fluid Systems TFCS (two tested for replicability evaluation - identified as 5956 and 5957)
Purification Products Company NF 500

These membranes were chosen on the following bases: 1) commercial availability; 2) availability of the appropriate size membranes (diameter and length) to allow testing with our apparatus. Other membranes from other manufacuturers or distributors have been identified after the project testing period. It may be desirable to do preliminary testing of these membranes prior to final membrane selection.

2.2 Phase One

Short term testing of the nanofiltration membranes was carried out in Phase One evaluations. Each membrane was tested over a 24-hour period in which the feed water was made up in the laboratory using the source water chemistry as a recipe. Table 1 contains water quality information for the Hopi High School wells obtained from the DBSA report. We used worst case water quality data for our laboratory recipes, knowing that though this doesn't reflect typical water quality at the high schools, it was prudent to put the system under the most rigorous conditions. Analyses are still needed for strontium, total and dissolved iron, and heterotrophic plate count. These will be obtained prior to full scale design Both reject and product streams were recycled back into the reservoir after passage through the membranes. Samples were obtained at 0.5, 1, 2, 4, 8, and 24 hours. The samples were analyzed for the following parameten:

1) Feed Water: Electrical conductivity, pH, flow, pressure, Cl^-, SO_4^{2-}, Ca^{2+}, Mg^{2+};

2) Permeate: Electrical conductivity, pH, flow, pressure, Cl^-, SO_4^{2-}, Ca^{2+}, Mg^{2+};

3) Reject: Flow, electrical conductivity.

Analyses of anions was conducted on a Wescan Ion Chromatograph or a Dionex Ion Chromatograph equipped with a conductivity detector. Cations were measured on a Perkin Elmer Atomic Absorption Spectrophotometer equipped with a flame furnace or a Hach DR 3000 Spectmphotometer. Temperature and pH were measured on a Coining Model 340 pH meter. Electrical conductivity was measured on an Orion Model 160 Conductivity Meter using an Orion Model 012210 Conductivity Probe.

Flow was maintained at approximately three gal/min (11.4 liters/min) per membrane at 10% recovery. The two best performing membranes were retested under Phase One conditions with additional specific ions analyses performed. Additionally, each membrane was tested to determine product recovery versus pressure variation.

Figures 3 and 4 show schematic diagrams of the membrane testing apparatus. The apparatus consisted of the feed reservoir, 5 µm cartridge pie-filters, the high pressure pump, four membrane pressure vessels, flow meters for the permeate and reject streams, pressure gauges associated with each pressure vessel, and associated valves and tubing. The influent water was introduced from the reservoir and delivered to the membranes by the high pressure pump. Pressure gauges upstream from each pressure vessel measured influent pressure to the membranes. Both the permeate and reject streams were recycled back to the reservoir.

2.3 Phase Two

The two best performing membranes (based on water quality of permeate and pressure requirements) from the Phase One testing underwent longer term testing to evaluate possible performance changes over time. The configuration of the testing apparatus and feed reservoir were the same as in Phase One testing (Figures 3 and 4). The reject and product streams were again recirculated back into the feed reservoir.

Phase Two testing was conducted over a ten-day time period. Flow was maintained at approximately three gal/min (11.4 liters/min) and the membranes operated at 10% recovery. Samples were taken at 0.5, 1, 2, 4, 8, and every 24 hours thereafter. The samples were analyzed for the following parameters:

1) Feed Water: Electrical conductivity, pH, pressure, temperature, flow, Ca^{2+}, Mg^{2+}, Na^+, SO_4^{2-}, and Cl^-.

2) Permeate: Electrical conductivity, pH, pressure, temperature, flow. Ca^{2+}, Mg^{2+}, Na^+, SO_4^{2-}, and Cl^-.

3) Reject: Electrical conductivity, pH, flow.

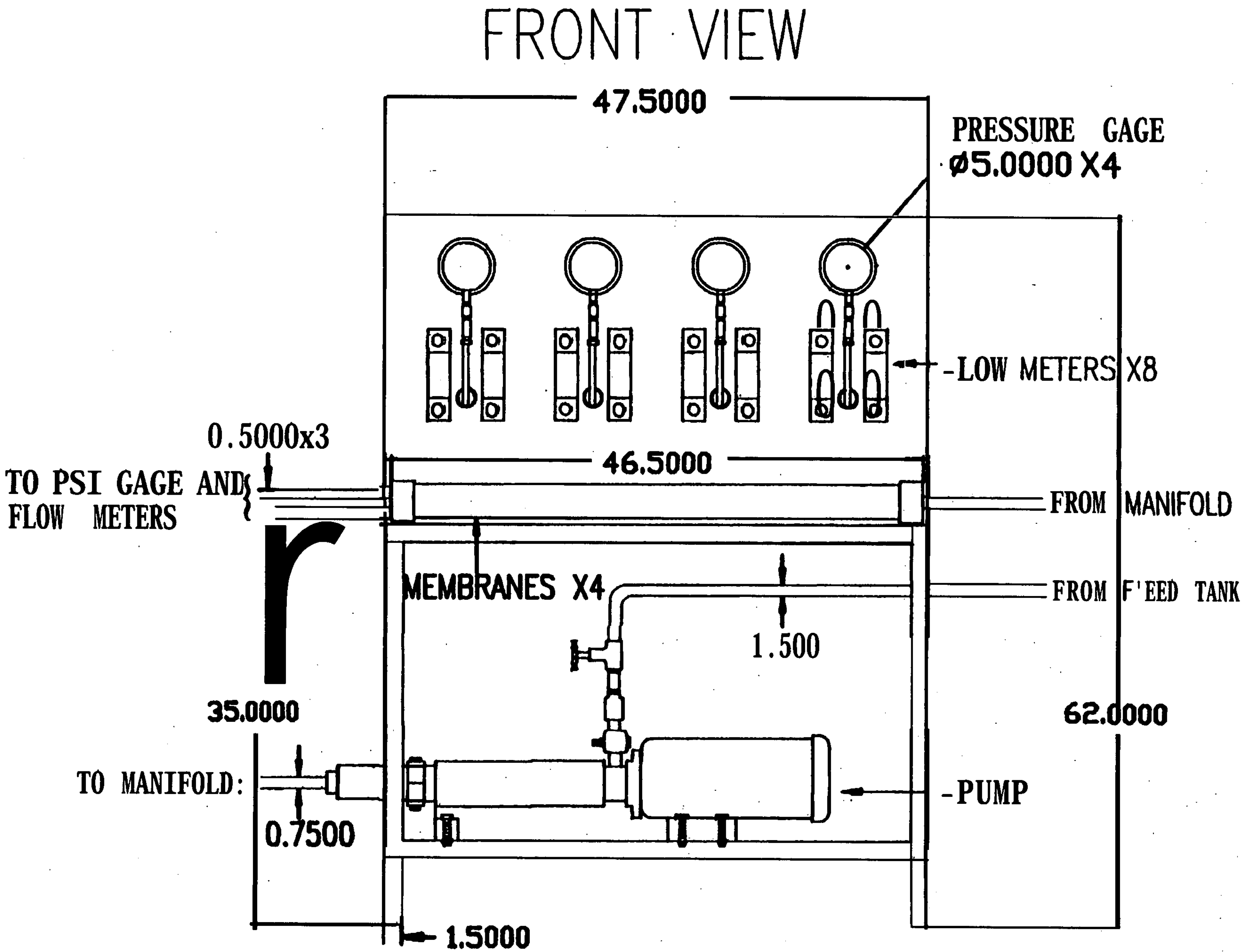


Figure3. Front View Schematic of the Membrane Testing Apparatus.

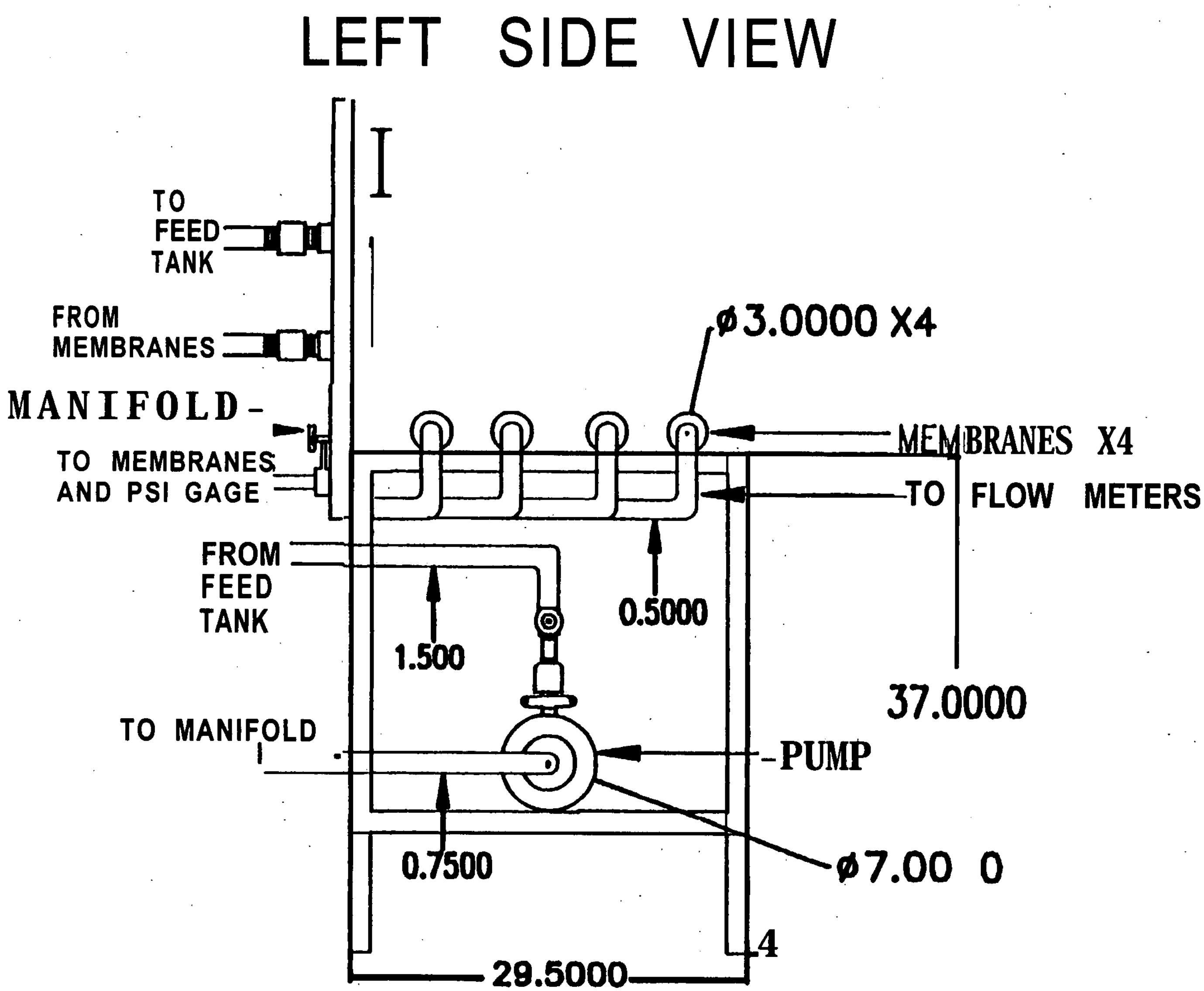


Figure4. Side View Schematic of the Membrane Testing Apparatus.

2.4 On-Site

The original proposal described testing only up through Phase Two evaluations. However, during the course of the project., communication was maintained with the Hopi Natural Resources and Water Resources agencies. Arnold Taylor, Director of Natural Resources, and Nat Nutongla, Head of Water Resources, were kept informed of the project's progress. We explored with them the possibility of testing the membranes on site at the high school and were put in touch with Tony Laban, Facilities Manager at the Hopi High School. Mr. Laban, who works for the Bureau of Indian Affairs, arranged for us to have access to the pump house at Well #1. We were able to install the testing apparatus with modifications to the facility's electrical and plumbing connections. Therefore, with much help from the tribal officials and facilities' management staff at the school, we were able to accomplish on-site testing, which was additional to the original project scope. it should be noted that this testing was done at no additional cost to the Bureau of Reclamation Approximately ten trips to the Hopi Reservation (ca. 300 miles, 482.8 km, round trip) were required for the setup and testing.

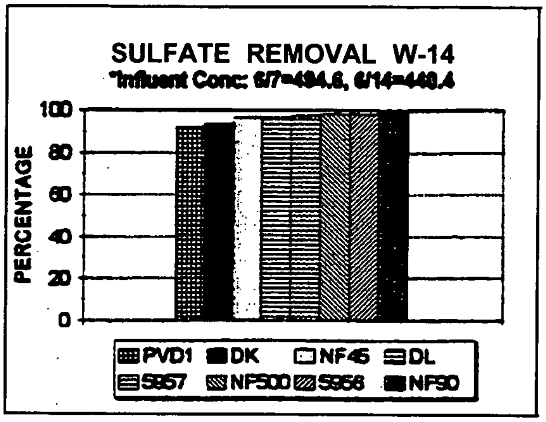
The two membranes tested in Phase Two were evaluated, along with one more membrane chosen from the original group of membranes. The tests were run for three days under conditions similar to Phase Two testing, i.e. approximately three gallons per minute, with 10% recovery. Additional testing was done on one of the membranes with the testing equipment reconfigured to run in series as opposed to in parallel. Three membranes of the same make were used to more closely simulate full scale operations. Samples were analyzed for the same parameters as in Phase Two testing.

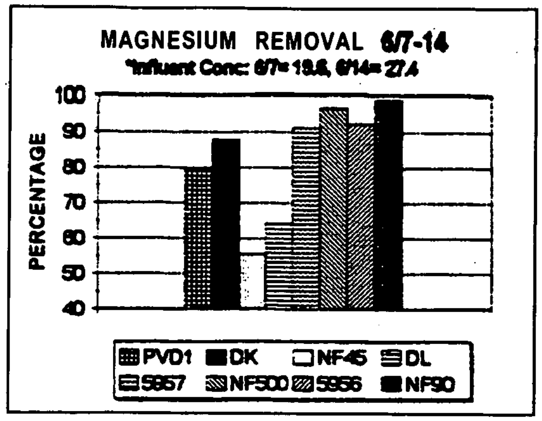
3.0 RESULTS AND DISCUSSION

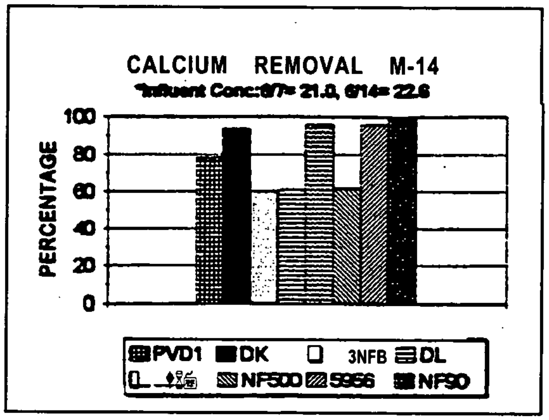
3.1 Phase One Testing

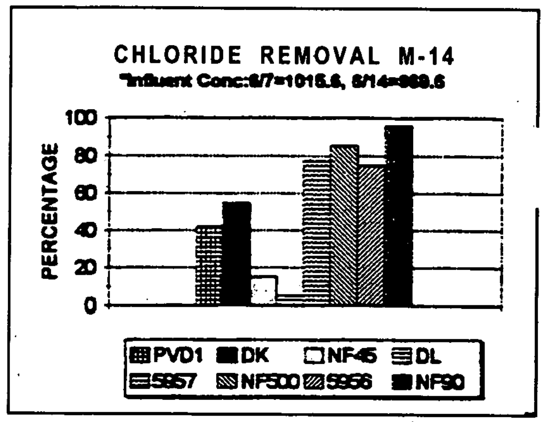
The Phase One testing occurred on 6/7, 6/14, and 6/28. As described in the methodology section this work consisted of membrane evaluation over a 24-hour period. Measured parameters included flow (influent, permeate, reject), system pressure, conductivity, SO_4^{2-}, Cl^-, Ca^{2+}, Mg^{2+}, permeate recovery, and salt rejection. The runs conducted on 6/7 and 6/14 included all eight membranes, while the 6/28 run was a replicate run for the two best performing membranes as determined by the two previous tests.

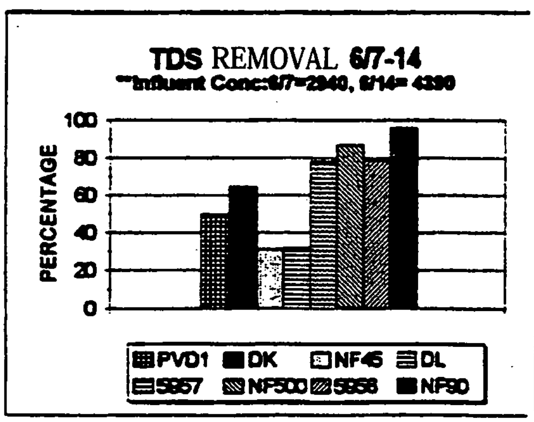
Results for the 6/7 and 6/14 runs are shown in Figure 5 and Appendix A. Also included are data sheets for all of the runs. The figures and the following synopsis of the data are based on the 24-hour sample taken for each membrane. All of the membranes exceeded 90% rejection of SO_4^{2-}. The FilmTec NF90 and the PPCM NF-500 rejected greater than 95% of the influent Mg^{2+}, while the Mg^{2+} rejection by the other membranes was as follows: Ruid Systems membranes (5956 and 5957) greater than 90%; the DeSal DK approximately 88%; the Hydranautics PVD1 80%; the DeSal DL less than 65%; and the FilmTec NF45 approximately 55%. Similar rejections were observed for Ca^{2+} rejection except for the PPCM NF-500 membrane which had about a 60%











* units = mg/l
** units = uS/cm

Figure 5. Results of Phase One Testing, 6/7/94 & 6/14/94

removal. Inspection of the calcium data from earlier PPCM samples, however, shows approximately 90-95% rejection, which is probably a more accurate estimation of the rejection.

Rejection of chloride showed the greatest disparity among the membranes. The FiiTec NF90 rejected 95% of the chloride, while the PPCM NF500 and the Fluid System membranes rejected 85% and 75%, respectively. The DeSal DK, the Hydranautics PVD1, the FilmTec NF45, and the DeSal DL membranes rejected approximately 55%, 42%. 15%, and 5% of the chloride respectively. Total dissolved solids removal, as measured by conductivity, showed similar patterns with removals as follows: FiiTec NF90 - 95%, PPCM NF-500 - 86%. Fluid Systems (5956 & 5957) - 79%, DeSal DK - 63%, Hydranautics PVD1 - 50%, FiiTec NF45 - 30%, and the DeSal DL - 30%.

The pressures required for the different membranes to achieve an approximate 10% recovery varied from membrane to membrane. The following initial pressures were recorded for the different membranes at the beginning of the runs (24-hr pressures were influenced by temperature effects and therefore are not used for comparison): FiiTec NF45 - 136 psi (93.8 N/cm'); FilmTec NF90 - 108 psi (74.5 N/cm*); PPCM NF-500 - 106 psi (73.1 N/cm^3); Desal DL - 105 psi (72.4 N/cm'); Hydranautics PVD1 - 80 psi (55.2 N/cm*); Desal DK - 102 psi (70.3 N/cm'); Fluid Systems TFCS (5956) - 139 psi (95.8 N/cm^2); Fluid Systems TFCS (5957) - 141 psi (97.2 N/cm^2). Initial startup temperatures were the same for every test. approximately 20° C $\pm$ 1° (-68" F).

Testing was also conducted to evaluate recovery and conductivity variation with changes in pressure. The influent startup temperature was the same for all of the membranes. All of the membranes showed an initial decrease in permeate conductivity as pressure increased. But at some point, typically between 120 - 140 psi (82.7 - 96.5 N/cm^2), the conductivity of the permeate began to increase. These data are included in Appendix A with the other Phase One information.

On 6/28 Phase One testing was again conducted on the FilmTec NF90 and the PPCM NP-500 membranes for replication purposes. Figure 6 and Appendix A show the results of this run. Both membranes rejected almost 100% of the influent SO_4^{2-}, Mg^{2+}, and Ca^{2+}. The FiiTec NF90 removed almost 100% of the influent Na' and greater than 95% of the Cl^-, while the PPCM NF500 rejected approximately 83% and 89% of these ions, respectively. Total dissolved solids rejection was almost 98% for the NF90 and approximately 92% for the NF-500. Both membranes again showed excellent rejection capabilities. Higher pressures were observed for both membranes. This was likely due to iron oxide fouling caused by inappropriate fittings supplied by a local distributor. The fittings were subsequently changed and membrane cleaning with an acid solution was performed

Based on permeate quality and on operating pressures, the FilmTec NF90 and the PPCM NF-500 are the best performing membranes as determined by this short term testing. Though the Hydranautics membrane operates at pressures 20% lower than these two membranes, the permeate quality is substantially lower. Therefore, these two membranes were chosen to undergo the Phase Two long term testing.

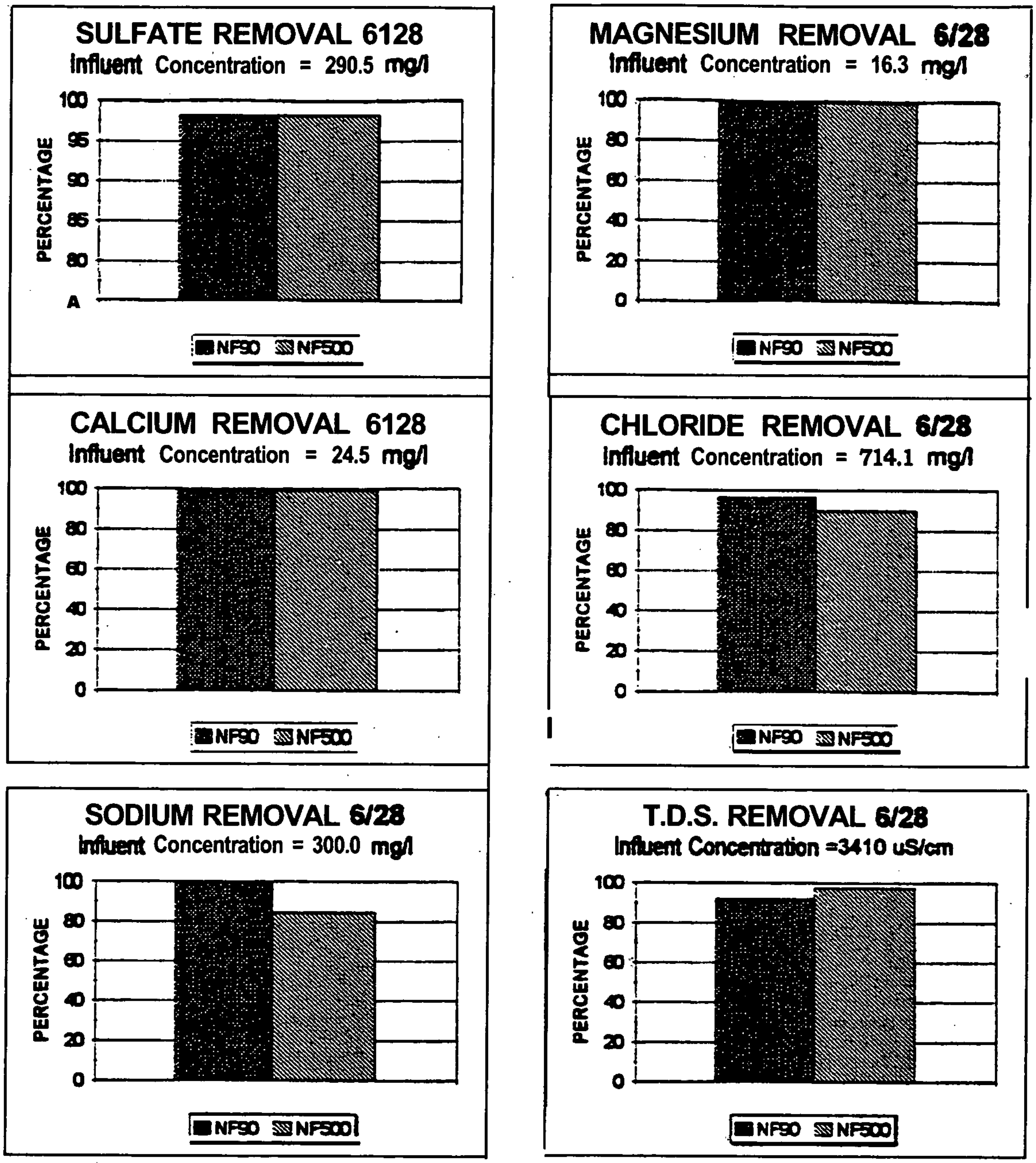


Figure 6. Results of Phase One Testing, 6/28/94

3.2 Phase Two Testing

The Phase Two testing was begun on 8/9/94 and lasted for ten days. Specific ion analyses were performed through the 24-hour sample. Thereafter only pH, conductivity, temperature, pressure, and flows were measured, except for the 10-day sample which received the full suite of analyses. Figure 7 and Appendix B show the results of this nm. A small increase in conductivity of the NF90 permeate (72 to 119 uS/cm) and no significant increase in the conductivity of the NP-500 was observed, suggesting little increase in the specific ion concentrations. During this longer term testing temperature again increased, stabilizing between 37" and 38" C (-99" F). This temperature increase was accompanied by a corresponding decrease in operating pressure, from 100 psi to 89 psi (68.9 to 61.4 N/cm^2) for the PPCM NF-500 and 128 psi to 99 psi (88.3 to 68.3 N/cm^2) for the FilmTec NF90. However, as noted above, the permeate quality did not deteriorate for the NF-500 membrane and only decreased slightly for the NF90 membrane.

At the ten-day sample a total dissolved solids rejection (as measured by conductivity) of 93% was measured for the PPCM NF-500 membrane and 97% for the FilmTec NF90. The last sample for which specific ions were measured, the 24-hour sample, showed rejections similar to the other Phase One tests. The NF90 membrane rejected slightly more of the Cl^-, Na'. and TDS, while both membranes rejected almost 100% of the Ca^{2+}, Mg^{2+}, and SO_4^{2-}.

Pressure measurements showed that the membrane cleaning performed after the 6/28 run had mixed results. The PPCM NF-500 membrane appears to have recovered completely, with an initial pressure reading of 100 psi (68.9 N/cm^2) for an approximately 10% recovery. This is comparable to the initial pressures observed in the first run on 6/7, approximately 106 psi (73.1 N/cm^2) for the same recovery. However, the FilmTec NF90 membrane cleaning doesn't appear to have been as successful, with an initial pressure reading of 128 psi (88.3 N/cm^2) for an approximate 10% recovery. This is a decrease from the 6/28 initial reading of 138 psi (95.1 N/cm^2), but still greater than the 108 psi (74.5 N/cm^2) recorded on the 6/7 run. Normally we would simply replace the slightly fouled membrane with a new one, but as the NF90 is still considered developmental, we were not able to obtain any more membranes until November 1994, which was too late to run the tests again. However, the results are still useful in interpreting the membrane capabilities, as the fouling did not appear to be excessive.

Both membranes performed as well in the longer term testing as they did in the short term tests. The FilmTec NF90 produces a higher quality permeate, while operating at a similar pressure.

3.3 On-Site Testing

On-site testing was conducted at the Hopi High School using three membranes: FilmTec NF90, PPCM NF-500, and Fluid Systems TFCS (5956). Ideally we would have been able to run the test for ten days. However, at the time we were conducting the tests hvo of the three wells were out of service for testing and repairs. Additionally, we had to dispose of the test water by simply draining it into an adjoining field., which may have caused some misperceptions about wasting water in this arid climate. Therefore, our extended run lasted slightly over two days. Figure 8 and Appendix C show the results of this run Samples were taken at 0.5, 1.0, 2.0, 4.0, and 52.0 hours and analyzed for the same parameters as in Phase One and Phase Two testing. In addition to using the actual

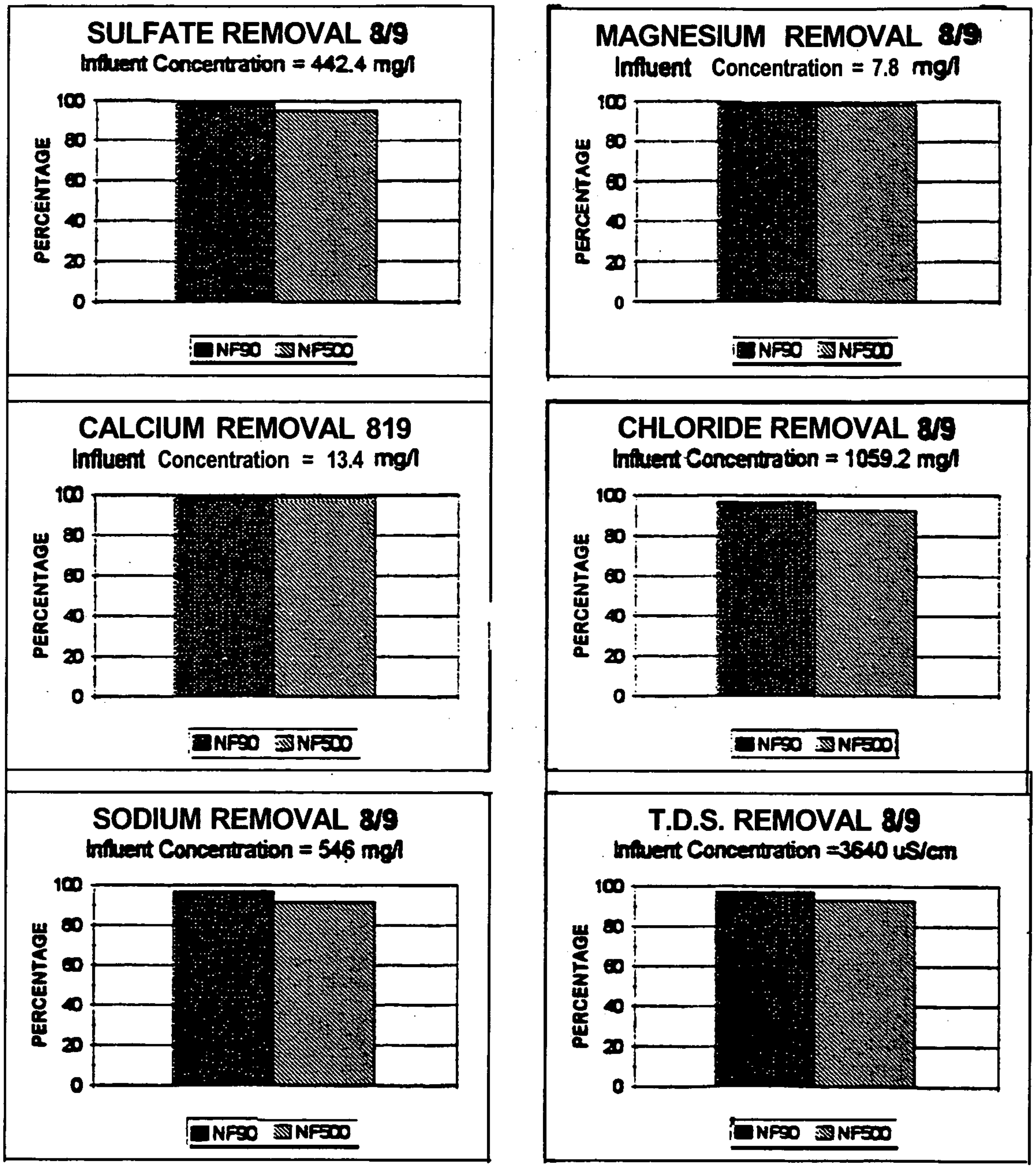


Figure 7. **Results** of Phase Two **Testing, 8/9/94**

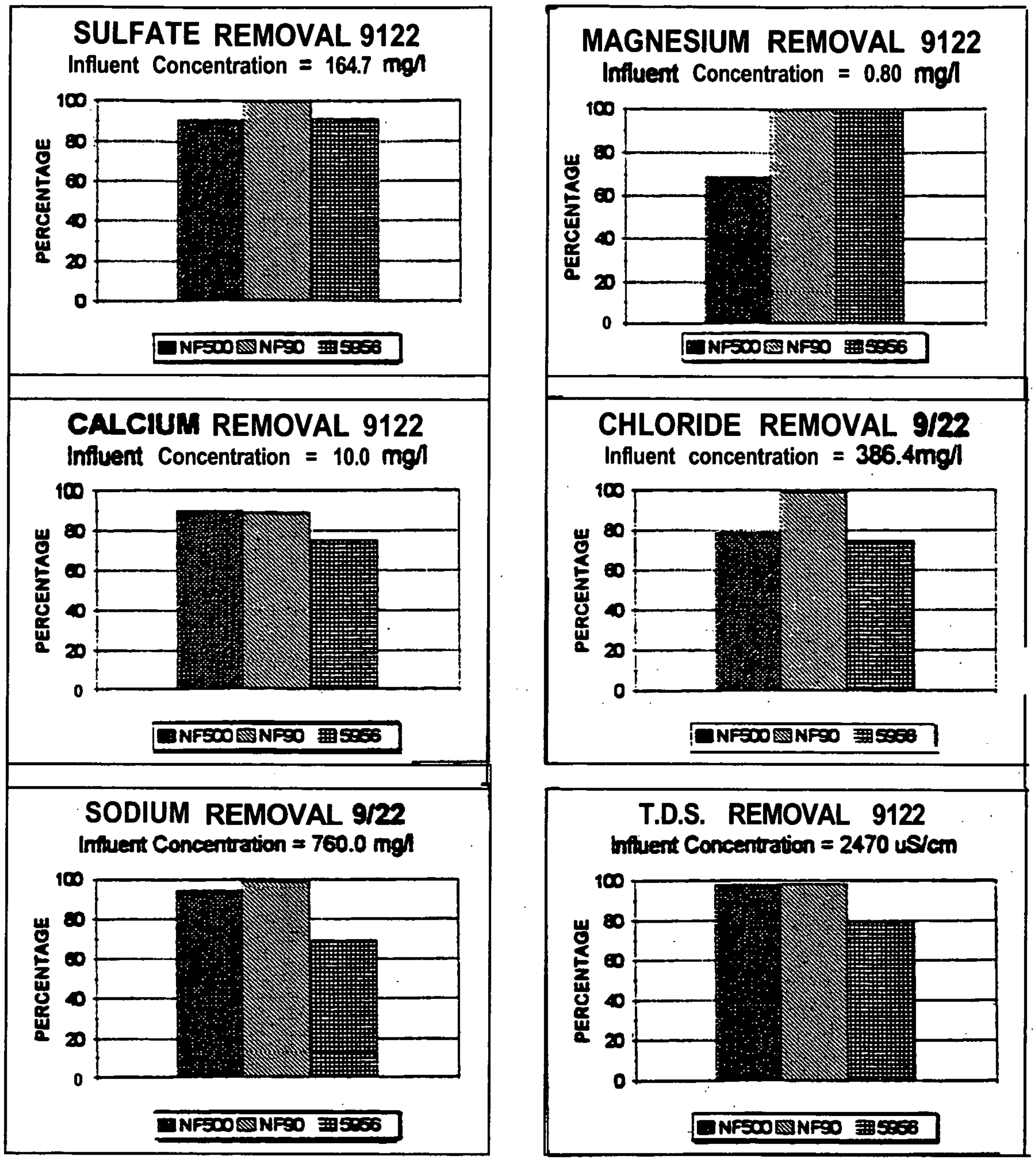


Figure 8. Results of On-Site Testing, 9/22/94.

groundwater we were able to avoid the temperature effects that affected the laboratory testing. The temperature remained at about 22°C (71.6" F) throughout the test.

The 52-hour samples were used to evaluate rejections for each of the membranes. The NF90 membrane achieved close to 100% rejections of Mg^{2+}, Na', SO_4^{2-}, and TDS. Rejection of Ca^{2+} was only 90%, however the influent Ca^{2+} concentration was low, so any measureable amount in the permeate (in this case 0.9 mg/l) will make the rejection appear somewhat low. This also occurred for Mg^{2+} and Ca $^{2+}$ rejection by the PPCM NF-500 membrane (0.25 and 1.1 mg/l respectively), but which calculates as only a 68% and 90 % rejection The PPCM NF-500 rejected almost 100% of the SO_4^{2-} and Na', and approximately 98% of the Cl^- and TDS. The Fluid Systems TFCS membrane rejected almost 100% of the Mg^{2+}, 91% of the SO_4^{2-}, 75% of the Cl^- and Ca^{2+}, about 70% of the Na', and more than 80% of the TDS.

All of the membranes requited higher pressures to achieve a 10% recovery during the on-site tests than in the lab tests. The reason for this is not known at this time, but these pressures are still well below those used for reverse osmosis membranes. Further membrane testing on-site with new membranes would allow examination of this disparity in operating pressures. The on-site tests were very informative for a number of reasons. These tests provided confirmation of laboratory data, showing that the two best perfonning membranes also performed well in the field The tests also showed that laboratory simulation of the treatment process provides a reasonable estimation of on-site performance. It was also very informative to be able to interact with the people who are involved in this issue and to become aware of the various perspectives. These people included the Hopi Natural Resources and Water Resources staff, the Hopi High School facilities staff and BIA personnel, and the teachers, staff and students of Hopi High School.

In summary, it appears that the two membranes identified in the laboratory testing (FilmTec NF90 and PPCM NF-500) also performed well in the on-site evaluations. The FilmTec NF90 produces a higher quality product water, achieving a higher Cl^- and TDS removal than the PPCM NF-500. Both membranes operate at similar pressures, so there appears to be no economic basis with respect to energy consumption to choose one over the other. Therefore, looking purely at permeate quality it would appear that the FilmTec NF90 would be the preferred membrane.

4.0 PRELIMINARY DESIGN ESTIMATES

Preliminary design estimates were solicited from two firms based on the two best performing membranes. Summaries of these designs are presented below. Figure 9 shows a conceptual design for a full scale system. The designs were based on a product water flow of 50,000 gallons per day using a water analysis performed on a 10/06/87 sampling. The pilot scale testing used the high end of concentrations observed to look at worst case influent water quality. The preliminary designs are based on a more 'typical' water quality analysis. This water quality analysis is presented in Appendix D.

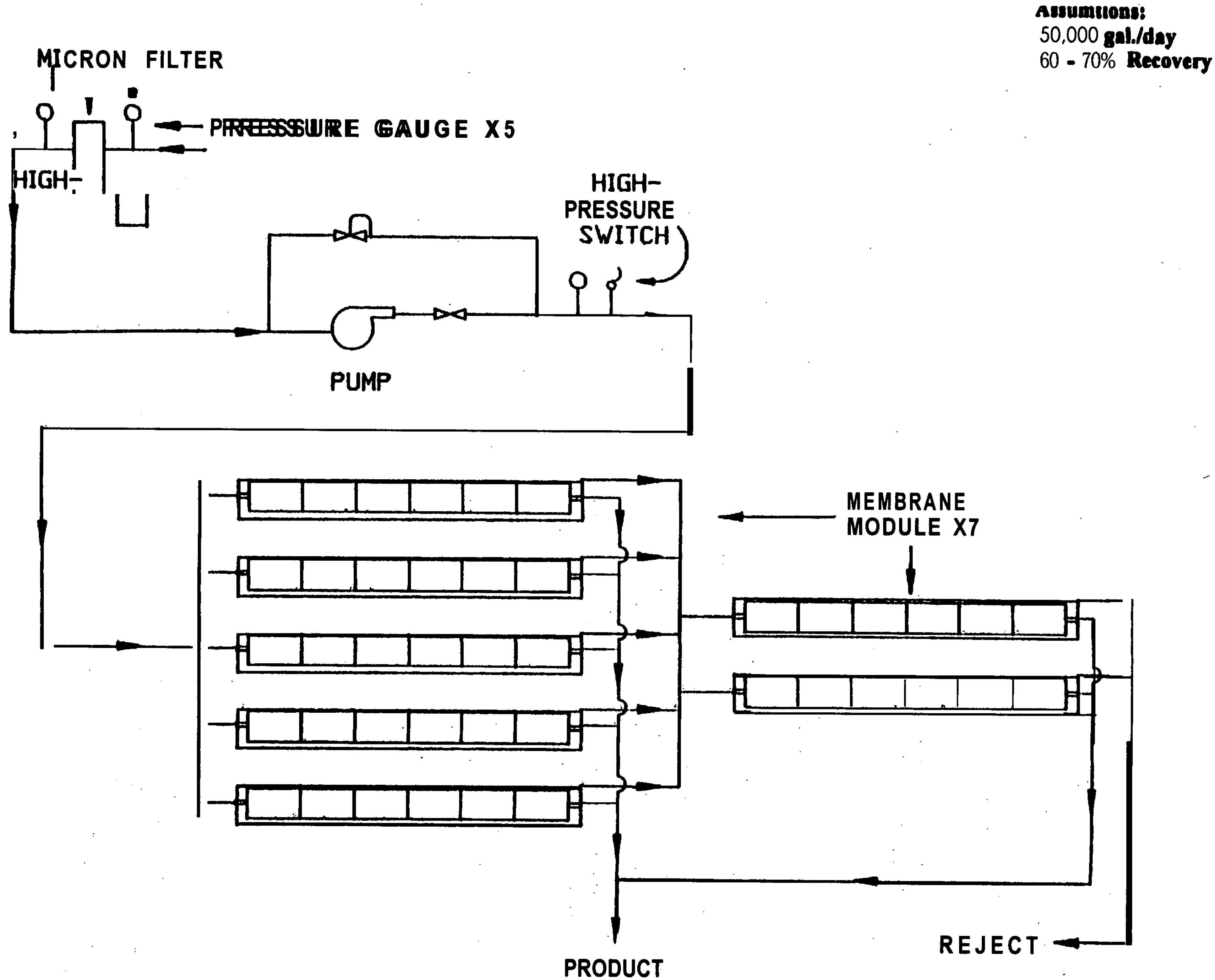


Figure 9. **Conceptual Design of a Full Scale Production System.**

4.1 Design One

A summary of the design components is as follows: twelve nanofiltration elements, three high pressure membrane vessels, one high pressure pump, 5 um pre-filtration cartridges, and associated piping, gauges, and valves. The estimated cost for this system is $62,750, excluding installation, start-up, operator training, and any applicable taxes. Membrane replacement is expected every three years at a cost of $13,500. No estimates were provided for product recovery or permeate or reject quality.

4.2 Design Two

A summary of the design components is as follows: two booster pumps, 5 um pre-filtration cartridge, high pressure pump, 35 membranes, five pressure vessels, electric control panel. and associated piping, valves, gauges, and flowmeters. Provision was also made for a water softener if needed. The estimated cost of this system is $83,220 and does not include installation and start-up costs. Addition of a water softener would add approximately $7,000 to the system costs. Full installation by the vendor is offered at a cost of $15,000. The estimated product water quality is 296 ppm ± 10 % and the reject stream would be approximately 13,000 ppm.

4.3 Brine Disposal

The requests for preliminary design estimates did not include the issue of brine disposal. This will be addressed prior to any full scale design implementation and will need to be discussed with the appropriate Hopi Tribe agencies in order to comply with tribal regulations. Some of the candidate approaches that may be investigated include discharge to sewage lagoons, spray irrigation, discharge to lined and unlined evaporation ponds, discharge to infiltration ponds, and discharge to wetlands with salt tolerant plants.

4.4 Pretreatment

Other than 5 µm cartridge filtration, pretreatment was not addressed in this report. Also, not all water quality parameters required for determining pretreatment were measured, i.e. Sr^{2+}, dissolved and total iron, HPC (heterotrophic plate count), turbidity, and SDI (silt density index). These need to be considered in any follow-on design of a demonstration pilot plant and/or full-scale system.

5.0 Discussions and Meetings

Meetings were held with users of the water and with appropriate tribal and agency representatives to discuss the water treatment testing. Results of these meetings and discussions are presented below.

5.1 Meeting with High School Teachers

The high school's teachers live in the community adjacent to the high school and are connected to the high school's water system. They have expressed concern about the water quality and many use bottled water and individual treatment systems. The project PI gave a presentation and demonstration for the teachers. A number of the teachers later filled water containers with product water from the pilot scale treatment system.. There was strong interest by the teachers in finding some resolution to the water quality problems they were experiencing.

5.2 Meeting with Officials

A meeting was held on-site attended by representatives of the Hopi Tribe, the Bureau of Indian Affairs, the Bureau of Reclamation. the high school's facilities management staff, and Northern Arizona University. Arnold Taylor, Manager of the Hopi Tribe's Department of Natural Resources, indicated that his Water Resources group was actively investigating solutions to the high school's water quality problems. Alternatives included redrilling of the production wells, establishment of a new well field in a different part of the N Aquifer, and on-site treatment. Stanley Hightower of the Bureau of Reclamation discussed funding for the project with Mr. Taylor and with the representative of the Bureau of Indian Affairs, who oversees facilities operations at the high school. The result of the meeting and discussions was that there appears to be sufficient interest by all parties to investigate possible funding for the full scale system if it is shown that it can successfully address the water quality problems at the high school.

6.0 CONCLUSIONS AND RECOMMENDATIONS

- Short and long term laboratory testing identified two nanofiltration membranes that significantly reduced the TDS. sodium, chloride, and sulfate levels of the feed water.

- Additional pilot-testing conducted on-site at the high school showed that the two membranes achieved significant reductions in the above parameters with the actual ground water from the high school wells. Projections based on the on-site testing indicate that at 80% recovery the final product water would have an electrical conductivity of 275-325 uS/cm (-250-300 mg/l TDS).

- Test data and information provided by the two design companies indicate the production system will require the nanofihration system and a pretreatment system similar to the conceptual design shown in Figure 9. The capital cost of this system. including installation and civil works is estimated to be $83,000 to $105,000.

- The 0 & M costs for this water, including membrane and cartridge replacement and electrical power is approximately $0.95/1000 gallons or $17,340 per year. This does not include the capital costs of approximately $105,000 and the costs for monitoring and checkout for the first year by Northern Arizona University of approximately $20,000. The capital costs and first year checkout costs amount to approximately $2.50 per installed gallon per day (based on 50,000 gpd production). Assuming these costs are covered by appropriate grants and/or matching funds and don't require amortization, over a 20-year project life this will raise the cost of the treated water to approximately $1.29 per 1000 gallons.

- Based on meetings with Tribal officials and the Bureau of Indian Affairs representative there appears to be sufficient interest to investigate funding for the full scale system.

- Design of a pilot demonstration facility or full-scale system should be preceded by additional analysis of pre-treatment needs, which would include at a minimum analysis of well water for Sr^{2+}, HPC, SDI, total and dissolved iron, and silica. Longer term on-site testing may also be beneficial for evaluation of pre-treatment needs. Additionally, brine disposal options would have to be investigated for both technical and regulatory viability.

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APPENDICES

Appendix A

Phase 1 Testing Results

Run of 6/7/94

MEMBRANE: MFG. Filmtec MODEL# NF90

FEEDWATER		Cations (mg/l)		Anions (mg/l)	
Temperature (deg c)	19.1	Ca	21.0	SO4	494.60
pH	9.03	Mg	19.6	Cl	1015.60
Conductivity (uS/cm)	2940	Na	n/a		

PERMEATE

HOUR	TEMP. (deg c)	pH	COND. (uS/cm)	PRESS. (psi)	FLOW (gpm) PERM.	REJECT
0.5	21.3	9.22	87.8		0.28	n/a*
1.0	22.9	9.55	84.9	108.0107.0	0.27	nta
20	25.9	9.36	83.8	105.0	0.28	n/a
4.0	28.9	8.95	88.8	1020	0.29	n/a
8.0	33.3	9.53	111.2	85.0	0.28	230
24.0	36.8	8.94	116.5	84.0	0.26	2.40
REJECT24hr	36.8	8.72	3570	84.0	240	n/a

HOUR	ca	Mg	Na	SO4	cl
0.5	280	1.40	n/a	1.5	28.40
1.0	3.40	0.60	n/a	1.7	25.00
20	1.40	210	n/a	b/d	210.30
4.0	0.20	0.50	n/a	23.0	247.50
8.0	0.10	0.70	n/a	23.1	84.40
24.0	0.20	0.70	n/a	b/d	39.90
REJECT24hr	14.60	21.10	n/a	395.6	1128.40

ion values = mg/l

Run of 6/7/94

MEMBRANE: MFG. Desal **MODEL#** DL

FEEDWATER		Cations (mg/l)		Anions (mg/l)	
Temperature (de9 c)	19.1	ca	21.00	so4	494.60
pH	9.0	Mg	19.60	Cl	1015.60
Conductivity (uS/cm)	2940	Na	n/a		

PERMEATE

HOUR	TEMP. (deg c)	pH	COND. (uS/cm)	PRESS. (psi)	FLOW (gpm) PERM.	REJECT
0.5	21.30	8.69	1615	105.0	0.33	n/a
1.0	23.20	8.81	1640	194.0	0.37	n/a
20	26.20	8.78	1693	101.0	0.38	n/a
4.0	28.90	8.58	1751	97.0	0.40	n/a
8.0	33.50	8.79	1922	75.0	0.33	2.80
24.0	36.80	8.63	2020	720	0.36	280
REJECT24hr	36.70	8.76	3340	720	280	n/a

HOUR	ca	Mg	Na	SO4	Cl
0.5	6.70	3.70	da	404.5	727.2
1.0	6.70	4.70	n/a	406.2	610.2
20	5.30	5.60	da	77.0	881.7
4.0	5.20	6.10	n/a	220.4	645.4
8.0	6.60	7.70	n/a	46.8	1130.0
24.0	8.30	7.00	nh	b/d	983.3
REJECT24hr	23.40	31.20	n/a	6115	1137.9

* b/d = below detection, n/a = not available

ion values = mg/l

Run of 6/7/94

MEMBRANE: MFG. Filmtec MODEL# NF45

FEEDWATER		Cations (mg/l)	Anions (mg/l)
Temperature (deg C)	19.1	Ca 21.06	so4 494.66
pH	9.0	Mg 19.66	cl 1015.60
conductivity (uS/cm)	2940.0	Na nia	

PERMEATE

HOUR	TEMP. (deg c)	pH	COND. (uS/cm)	PRESS. (psi)	FLOW (gpm) PERM.	REJECT
0.5	21.36	8.67	1799.0	105.00	0.33	n/a
1.0	23.30	8.80	1831.0	135.00	0.36	n/a
20	26.20	8.77	1869.0	132.06	0.38	n/a
4.0	29.00	8.59	1919.0	128.06	0.40	n/a
8.0	33.70	8.81	1901.0	85.00	0.29	2.20
24.0	36.80	8.71	1997.0	82.00	0.30	2.20
REJECT24hr	36.70	8.81	3370.0	82.00	2.20	n/a

HOUR	Ca	Mg	Na	S04	Cl
0.5	8.30	5.40	n/a	321.3	884.1
1.0	9.10	5.00	n/a	181.7	765.1
20	9.10	7.00	n/a	175.0	849.5
4.0	10.20	7.40	nia	20.4	729.4
8.0	7.70	8.20	n/a	Wd	694.4
24.0	8.00	8.70	n/a	Wd	858.4
REJECT24hr	26.40	24.80	n/a	391.3	1055.7

Ion values = mg/l

Run of 6/7/94

MEMBRANE: MFG. PPCM MODELS NF500

FEEDWATER		Cations (mg/l)	Anions (mg/l)
Temperature (deg C)	19.1	ca 21.00	so4 494.60
pH	9.0	Mg 19.60	Cl 1015.50
Conductivity (us/cm)	2940.0	Na n/a	

PERMEATE

HOUR	TEMP. (deg c)	pH	COND. (uS/cm)	PRESS. (psi)	PERM.	REJECT
0.5	21.30	9.05	215.0	106.0	0.30	n/a
1.0	23.30	9.13	216.0	105.0	0.31	n/a
20	26.30	9.00	225.0	102.0	0.33	n/a
4.0	29.30	8.79	248.0	98.0	0.35	n/a
8.0	33.50	8.97	343.0	75.0	0.26	320
24.0	36.90	8.75	381.0	72.0	0.26	3.20
REJECT24hr	36.70	8.79	3410.0	72.0	3.20	n/a

HOUR	Ca	Mg	Na	SO4	Cl
0.5	1.60	0.20	n/a	3.9	80.7
1.0	18.60	1.00	n/a	6.3	82.2
20	210	0.60	n/a	36.2	303.8
4.0	0.50	0.10	n/a	66.8	150.3
8.0	1.70	0.20	n/a	26.8	232.3
24.0	8.20	020	n/a	Wd	150.3
REJECT24hr	38.40	13.00	n/a	306.9	1154.6

Ion values = mg/l

Run of 6/14/94

MEMBRANE: **MFG.** Fluid Svs. **MODEL#** SE5957

FEEDWATER		Cations (mg/l)	Anions (mg/l)
Temperature (deg C)	19.60	Ca 22.60	SO4 440.40
pH	9.06	Mg 27.40	Cl 969.60
Conductivity (uS/cm)	4390	Na n/a	

PERMEATE

HOUR	TEMP. (deg c)	pH	COND. (uS/cm)	PRESS. (psi)	FLOW (gpm) PERM.	REJECT
0.5	21.90	9.19	880.0	141.0	0.30	1.50
1.0	23.80	9.27	848.0	149.0	0.32	1.49
2 0	25.00	9.18	842.0	139.0	0.32	1.49
4.0	29.60	9.16	881.0	137.0	0.35	1.48
8.0	33.70	9.02	922.0	129.0	0.35	1.60
24.0	36.90	8.00	929.0	128.0	0.34	1.60
REJECT24hr	37.29	8.96	4340	128.0	0.34	1.60

HOUR	ca	Mg	Na	SO4	Cl
0.5	240	290	n/a	47.10	270.00
1.0	2.20	210	n/a	32.10	197.70
2.0	1.30	2.70	n/a	55.70	418.30
4.0	0.30	250	n/a	n/a	n/a
8.0	0.40	3.40	n/a	32.00	279.00
24.0	0.90	2.40	n/a	27.60	220.00
REJECT24hr	9.80	32.20	n/a	395.8	911.70

ion values = mg/l

Run of 6/14/94

MEMBRANE: **MFG.** Fluid Svs. **MODEL#** SE5956

FEEDWATER		Cations (mg/l)	Anions (mg/l)
Pressure (psi)	30.0	Ca 22.60	so4 440.40
Temperature (de9 C)	19.6	Mg 27.40	Cl 969.60
Flow (gpm)	3.0	Na n/a	
pH	9.06		
conductivity (us/cm)	4390		

PERMEATE

HOUR	TEMP. (deg c)	pH	COND. (uS/cm)	PRESS. (psi)	FLOW (gpm) PERM.	REJECT
0.5	22.20	9.24	957.0	139.0	0.30	1.60
1.0	24.00	9.13	928.0	138.0	0.31	1.60
2.0	25.00	9.17	931.0	137.0	0.32	1.55
4.0	29.70	9.17	961.0	135.0	0.35	1.55
8.0	33.60	9.01	932.0	126.0	0.32	1.70
24.0	37.20	8.85	949.0	127.0	0.32	1.60
REJECT24hr	37.20	8.98	4310	127.0	0.32	1.60

HOUR	Ca	Mg	Na	SO4	Cl
0.5	2.40	3.20	n/a	49.70	313.50
1.0	290	250	n/a	38.10	241.00
2 0	2.50	4.50	n/a	58.40	620.20
4.0	3.90	1.60	n/a	n/a	n/a
8.0	0.40	3.10	n/a	27.30	212.70
24.0	1.40	210	nfa	34.10	243.20
REJECT24hr	14.80	20.80	n/a	380.8	676.80

* b/d = below detection, n/a = not available

ion values = mg/l

Run of 6/14/94

MEMBRANE: M F G Hydranautics **MODEL#** PVD1

FEEDWATER		Cations (mg/l)	Anions (mg/l)
Temperature (deg C)	19.6	Ca 22.60	804 440.40
pH	9.06	Mg 27.40	Cl 969.60
Conductivity (uS/cm)	4390	Na n/a	

PERMEATE

HOUR	TEMP. (deg c)	pH	COND. (uS/cm)	PRESS. (psi)	FLOW (gpm) PERM.	REJECT
0.5	22.20	9.20	2080	80.00	0.32	4.80
1.0	24.00	9.13	2090	79.00	0.34	4.80
2.0	25.10	9.14	2090	78.00	0.35	4.80
4.0	20.80	9.13	2150	77.00	0.37	4.60
8.0	33.50	9.16	2160	76.00	0.48	4.20
24.0	37.30	9.06	2190	76.00	0.48	4.20
REJECT24hr	37.30	8.98	3890	76.00	0.48	4.29

HOUR	ca	Mg	Na	SO4	cl
0.5	7.00	6.50	n/a	14.00	589.10
1.0	3.40	3.30	da	17.00	661.80
2.0	6.00	6.70	n/a	20.70	894.90
4.0	8.80	6.80	n/a	n/a	n/a
8.0	4.80	7.70	n/a	11.50	624.50
24.0	4.90	5.60	n/a	11.50	558.00
REJECT24hr	13.20	24.60	n/a	335.8	79260

ion values = mg/l

Run of 6/14/94

MEMBRANE: MFG. Desal **MODEL#** DK

FEEDWATER		Cations (mg/l)	Anions (mg/l)
Temperature (deg C)	19.6	Ca 22.60	so4 440.60
pH	9.06	Mg 27.40	Cl 969.60
Conductivity (uS/cm)	4390	Na n/a	

PERMEATE

HOUR	TEMP. (deg c)	pH	COND. (uS/cm)	PRESS. (psi)	FLOW (gpm) PERM.	REJECT
0.5	22.2	9.10	1420	1020	0.32	3.40
1.0	24.0	9.11	1451	101.0	0.34	3.30
2 0	25.0	9.00	1470	100.0	0.36	3.30
4.0	29.8	9.13	1549	08.0	0.38	3.30
8.0	33.6	9.14	1538	96.0	0.44	3.00
24.0	37.2	9.01	1560	96.0	0.44	2.80
REJECT24hr	37.3	8.97	4020	96.0	0.44	280

HOUR	ca	Mg	Na	SO4	cl
0.5	280	3.40	n/a	40.0	374.20
1.0	1.40	4.60	n/a	n/a	349.00
2 0	3.00	3.10	n/a	da	872.80
4.0	3.10	3.80	n/a	n/a	da
8.0	1.50	3.40	n/a	11.5	328.80
24.0	0.90	3.30	n/a	11.5	438.30
REJECT24hr	13.60	28.80	n/a	366.6	821.40

ion values = mg/l

Run of 6/28/94

MEMBRANE: **MFG.** PPCM **MODELS** NF500

FEEDWATER		Cations (mg/l)		Anions (mg/l)	
Temperature (deg C)	20.6	Ca	24.50	so4	290.50
pH	9.01	Mg	18.30	Cl	714.10
Conductivity (uS/cm)	3410	Na	300		

PERMEATE

HOUR	TEMP. (deg c)	pH	COND. (uS/cm)	PRESS. (psi)	FLOW (gpm) PERM.	FLOW (gpm) REJECT
0.5	2210	8.86	238.0	119.0	0.31	3.60
1.0	23.80	8.84	236.0	117.0	0.32	3.60
20	24.70	8.70	237.0	115.0	0.33	3.50
4.0	26.50	8.79	255.0	1120	0.34	3.50
8.0	28.60	a62	267.0	110.0	0.36	3.80
24.0	33.20	8.37	262.0	111.0	0.31	3.40
REJECT24hr	33.80	8.68	3770.0	111.0	0.31	3.40

HOUR	ca	Mg	Na	SO4	Cl
0.5	0.14	0.12	47.90	15.50	46.30
1.0	0.13	0.10	46.10	8.75	43.10
20	0.19	0.14	40.00	31.00	60.00
4.0	0.21	0.16	41.30	43.80	67.30
8.0	0.25	0.18	37.10	31.50	72.00
24.0	0.15	0.10	46.10	5.25	72.00
REJECT24hr	15.60	18.30	440.00	390.0	760.00

ion values = mg/l

Run of 6/28/94

MEMBRANE: **MFG.** Filmtec **MODEL#** NF90

FEEDWATER		Cations (mg/l)		Anions (mg/l)	
Temperature (deg C)	2 0 . 6	Ca	24.50	so4	290.50
pH	9.01	Mg	16.30	Cl	714.10
conductivity (uS/cm)	3410	Na	300.0		

PERMEATE

HOUR	TEMP. (deg c)	pH	COND. (uS/cm)	PRESS. (psi)	FLOW (gpm) PERM.	FLOW (gpm) REJECT
0.5	2210	a95	85.50	138.0	0.32	210
1.0	23.80	9.31	78.10	135.0	0.34	200
20	24.70	9.23	80.00	133.0	0.35	1.90
4.0	26.50	9.21	83.20	131.0	0.37	1.90
8.0	28.60	9.24	86.40	130.0	0.39	1.80
24.0	34.20	8.61	81.20	134.0	0.37	1.80
REJECT24hr	33.80	8.64	3970.0	134.0	0.37	1.80

HOUR	ca	Mg	Na	SO4	cl
0.5	0.200	0.081	1.08	7.55	17.80
1.0	0.037	0.025	1.11	0.58	0.71
20	0.025	0.013	1.16	14.00	52.60
4.0	0.050	0.025	1.18	18.80	36.80
8.0	0.140	0.038	1.20	7.80	21.30
24.0	0.061	0.038	1.10	5.20	24.80
REJECT24hr	16.50	20.00	407.50	315.0	927.00

ion values = mg/l

Run of 6/7/94

Pressure variation results

FILMTEC NF90

PRESSURE	RECOVERY	CONDUCTIVITY
70	0.16	1062
80	0.19	109.8
90	024	103.1
100	029	98.3
110	0.34	87.7
120	0.39	63.8
130	0.42	83.5
140	0.48	82.7
150	0.52	87.5

DESAL - DL

'RESSURE	RECOVERY	CONDUCTIVITY
70	025	1905
80	0.32	1902
90	0.37	1824
100	0.42	1755
110	0.48	1702
120	0.53	1666
130	0.59	1642
140	0.65	1628
150	0.71	1644

PPCM NF500

PRESSURE	RECOVERY	CONDUCTIVITY
70	0.18	288
80	025	321
90	0.3	284
100	0.37	252
110	0.42	241
120	0.48	231
130	0.53	228
	0.59	225
140	0.63	237

FILMTEC NF45

PRESSURE	RECOVERY	CONDUCTIVITY
70	02	1958
80	025	1918
90	028	1878
100	0.33	1846
110	0.37	1843
120	0.39	1874
130	0.42	2010
140	0.42	2410
150	0.4	2480

Run of 6/14/94

Pressure variation results

FLUID SYS. SE5957

PRESSURE	RECOVERY	CONDUCTIVITY
70	0.16	860
80	0.18	1016
90	021	902
100	025	898
110	028	869
120	0.31	651
130	0.34	651
140	0.37	956
150	0.38	1010

FLUID SYS. SE5956

PRESSURE	RECOVERY	CONDUCTIVITY
70	0.16	981
80	0.19	1026
90	0.22	991
100	026	950
110	028	925
120	0.31	929
130	0.35	963
140	0.37	1226
150	0.38	1222

HYDRA. PVD1

PRESSURE	RECOVERY	CONDUCTIVITY
70	0.36	2160
80	0.41	2070
90	0.51	2010
100	0.59	1949
110	0.67	1888
120	0.75	1873
130	0.81	1873
140	0.89	1906
150	0.98	1961

DESAL DK

PRESSURE	RECOVERY	CONDUCTIVITY
70	025	1563
80	0.3	1683
90	0.36	1671
100	0.41	1579
110	0.48	1502
120	0.52	1443
130	0.58	1428
140	0.62	1460
150	0.68	1554

Run of 6128194

Pressure variation results

PPCM NF500			FILMTEC NF90		
PRESSURE	RECOVERY	CONDUCTIVITY	PRESSURE	RECOVERY	CONDUCTIVITY
70	a17	402	70	0.15	130.7
80	0.19	344	80	0.18	118.7
90	0.24	305	90	0.21	106.7
100	a29	285	loo	0.26	98.8
110	0.32	268	110	0.29	92.5
120	0.39	250	120	0.32	88.6
130	0.42	242	130	0.38	86
140	0.48	236	140	0.41	04.8
150	0.52	230	150	0.46	84.4

Run of 8/9/94

Pressure variation results

PPCM NF500			FILMTEC NF90		
PRESSURE	RECOVERY	CON330TIVITY	PRESSURE	RECOVERY	CONDUCTIVITY
70	0.18	282	70	0.16	114.5
a0	0.24		80	0.19	134.3
90	a3	259	90	0.22	119.2
100	0.35	247	100	0.29	105.4
110	0.4	237	110	0.34	102.5
120	0.48	231	120	0.38	97.8
130	0.53	222	130	0.42	93.6
140	0.58	225	140	0.48	93.4
150	0.61	225	150	0.52	92.5

Appendix B

Phase 2 Testing Results

Run of 8/09/94

MEMBRANE: MFG. PPCM **MODEL#** NF500

FEEDWATER		Cations (mg/l)		Anions (mg/l)	
Temperature (deg C)	20.2	Ca	13.40	so4	422.40
PH	8.6	Mg	7.80	Cl	1059.20
Conductivity (uS/cm)	3640	Na	546.0		

PERMEATE

HOUR	TEMP. (deg c)	pH	COND. (uS/cm)	PRESS. (psi)	FLOW (gpm) PERM.	REJECT
0.5	21.60	8.90	354.0	100.0	0.30	3.10
1.0	21.90	8.98	224.0	100.0	0.30	3.70
2.0	22.60	8.90	221.0	100.0	0.29	3.00
4.0	24.20	8.98	214.0	96.00	0.28	3.00
8.0	27.30	8.80	243.0	92.00	0.29	2.90
24.0	31.00	8.44	250.0	89.00	0.28	2.90
REJECT 24 hr	32.60	8.63	3970	89.00	0.28	2.90
48.0	35.70	8.71	267.0	86.00	0.28	2.80
72.0	37.30	8.80	261.0	87.00	0.28	2.80
96.0	37.90	8.32	252.0	87.00	0.28	2.80
120.0	37.70	8.62	249.0	87.00	0.28	2.80
144.0	37.80	8.90	242.0	86.00	0.27	2.80
168.0	37.70	8.71	240.0	88.00	0.26	2.70
192.0	37.90	9.02	248.0	89.00	0.26	2.80
216.0	38.50	9.10	247.0	89.00	0.26	2.70
240.0	36.10	9.09	247.0	89.00	0.27	2.60
REJECT 240 hr			4120			

HOUR	Ca	Mg	Na	SO4	Cl
0.5	0.263	0.113	45.80	87.7	199.00
1.0	0.088	0.063	45.40	38.3	131.30
2 0	0.100	0.063	39.50	26.5	104.90
4.0	0,113	0.075	38.50	24.3	108.00
8.0	0.100	0.630	42.80	12.5	64.50
24.0	0.050	0.100	44.80	21.4	76.10
REJECT 24 hr	13.80	8.20	600.0	506.5	3267.50

ion values = mg/l

Run of 8/09/94

MEMBRANE: MFG. Filmtec MODEL# NF90

FEEDWATER		**Cations (mg/l)**		Anions **(mg/l)**	
Temperature (de9 C	20.0	Ca	13.40	SO4	420.50
pH	8.6	Mg	7.80	Cl	1059.20
Conductivity(uS/cm)	3640	Na	546.0		

PERMEATE

HOUR	TEMP. (deg c)	pH	COND. (uS/cm)	PRESS. (psi)	FLOW (gpm) PERM.	REJECT
0.5	21.50	9.08	72.3	128.0	0.26	2.50
1.0	21.80	9.08	69.1	128.0	0.26	2.50
2.0	22.70	9.17	72.9	129.0	0.27	2.50
4.0	24.20	9.07	78.0	124.0	0.27	2.40
8.0	27.40	8.85	91.7	117.0	0.27	2.50
24.0	32.20	8.89	94.0	100.0	0.26	2.50
REJECT24hr	32.50	8.74	3990	100.0	0.26	2.50
48.0	35.50	8.83	108.9	97.0	0.27	2.40
72.0	37.30	8.74	111.9	97.0	0.27	2.50
96.0	38.00	8.58	114.3	97.0	0.27	2.50
120.0	38.00	8.76	173.5	97.0	0.27	2.50
144.0	37.60	8.79	108.2	98.0	0.26	2.40
168.0	37.50	8.82	110.1	98.0	0.25	2.50
192.0	37.80	9.00	119.2	99.0	0.25	2.50
216.0	38.50	9.04	121.1	99.0	0.25	2.50
240.0	36.70	9.29	119.1	99.0	0.25	2.50
REJECT240hr			4130			

HOUR	ca	Mg	Na	SO4	Cl
0.5	b/d	0.05	13.8	5.9	17.4
1.0	b/d	0.01	12.3	30.3	22.9
2.0	b/d	0.03	13.3	3.8	20.7
4.0	b/d	0.03	14.1	n/a	n/a
8.0	b/d	0.01	16.2	3.5	60.2
24.0	b/d	0.01	16.8	4.4	33.5
REJECT24hr	10.40	5.85	916.0	372.9	868.1

ion values = mg/l

Appendix C

On-Site Testing Resu lts

Run of 9/22/94

MEMBRANE: MFG. PPCM **MODEL#** NF500

FEEDWATER
Temperature (deg C) 21.1
pH 8.6
Conductivity (us/cm) 2470

Cations (mg/l)
Ca 10.0
Mg 0.8
Na 760.0

Anions (mg/l)
SO4 164.7
Cl 386.4

PERMEATE

HOUR	TEMP. (deg c)	pH	COND. (uS/cm)	PRESS. (psi)	FLOW (gpm) PERM.	REJECT
0.5	22.20	8.75	58.3	140.0	0.30	2.80
1.0	21.90	7.85	66.7	137.0	0.30	2.80
2.0	22.60	8.05	33.2	140.0	0.30	2.80
4.0	22.40	8.08	46.6	140.0	0 2 9	2.70
52.0	n/a	n/a	n/a	140.0	0.29	2.70

HOUR	Ca	Mg	Na	SO4	Cl
0.5	1.10	0.10	3.30	0.91	9 2 0
1.0	1.10	0.10	3.70	0.96	11.50
2.0	1.20	b/d	1.30	0.69	7.90
4.0	1 2 0	b/d	0.60	0.57	6.00
52.0	1.00	0.25	4.63	15.90	8 . 2

ion values = mg/l

Run of 9/22/94

MEMBRANE: MFG. Fluid Systems **MODEL#** 5956

FEEDWATER
Temperature (deg C) 21.1
PH 8.63
Conductivity (uS/cm) 2 4 7 0

Cations (mg/l)
Ca 10.0
Mg 0.8
Na 760.0

Anions (mg/l)
SO4 164.7
Cl 386.4

PERMEATE

HOUR	TEMP. (deg c)	pH	COND. (uS/cm)	PRESS. (psi)	FLOW (gpm) PERM.	REJECT
0.5	22.20	8.45	563.0	181.0	026	2.30
1.0	2220	7.87	588.0	182.0	0 2 6	2.30
2.0	22.30	7.88	491 .0	181.0	0.27	2.30
4.0	22.60	8.03	389.0	179.0	0.26	2.60
52.0	n/a	n/a	453.0	185.0	0 2 4	2.30

HOUR	Ca	Mg	Na	SO4	Cl
0.5	12.50	2.50	305.0	168.0	97.80
1.0	5.00	b/d	270.0	37.40	110.40
2.0	5.00	bid	267.5	2620	86.00
4.0	5.00	b/d	220.0	27.10	59.80
52.0	2.50	b/d	235.0	14.70	98.10

* b/d = below detection, n/a = not available

ion values = mg/l

Run of 9/22/94

MEMBRANE= MFG. FilmTec **MODEL#** NF90

FEEDWATER		**Cations (mg/l)**		**Anions (mg/l)**	
Temperature (deg C)	21.1	**Ca**	10.0	SO_4	**164.7**
PH	8.63	Mg	0.8	Cl	386.4
conductivity (us/cm)	2470	Na	760.0		

PERMEATE

HOUR	**TEMP. (deg c)**	**pH**	COND. **(uS/cm)**	PRESS. **(psi)**	FLOW (gpm) PERM.	REJECT
0.5	**22.20**	0.07	**37.2**	158.0	0.29	2.80
1.0	21.90	8.03	**38.4**		0.29	2.60
2.0	22.60	0.20	**35.3**	160.0 150.0	0.28	2.80
4.0	22.50	8.35	**33.2**	150.0	0.27	2.70
52.0	**n/a**	n/a	25.9	**n/a**	**n/a**	**n/a**

HOUR	**Ca**	**Mg**	Na	SO4	Cl
0.5	**0.90**	**b/d**	0.50	0.64	4.50
1.0	1.10	Wd	**0.60**	0.55	4.50
2.0	1.00	Wd	2.60	0.43	3.50
4.0	1.10	Wd	3.80	0.36	2.60
52.0	1.10	Wd	4.30	0.49	3.50

ion values = mg/l

Run of 9/22/94

Pressure variation results

NF70

	(RECOVERY)	
PRESS	REJECT	PERM
70	4.70	0.09
80	4.50	0.10
90	4.36	0.13
100	4.10	0.15
110	3.96	0.18
120	3.70	0.19
130	3.46	0.21
140	3.10	0.25
150	280	0.28
160	260	0.30
170	230	0.32
180	1.90	0.34
190	1.60	0.38
200	1.10	0.39

NF500

	(RECOVERY)	
PRESS	REJECT	PERM
70	4.20	0.12
80	4.00	0.13
90	3.80	0.16
100	3.60	0.19
110	3.40	0.21
120	320	024
130	290	028
140	2.70	0.30
150	250	0:33
160	230	0.37
170	210	0.39
180	1.80	0.42
190	1.50	0.45
200	1.10	0.48

Appendix D

Water Quality Analysis for Preliminary Design Estimates

Inorganic Chemical Analysis

Lab Name and Address:
Western Technologies, Inc.
3737 Easst Broadway Road
P.O. Box 21387
Phoenix, AZ 85038

Hopi Jr./Sr. High School - Well No. 3 **10/06/87**

Contaminant Name	Analysis Results (mg/l)
Arsenic	4.02
Barium	co. 1
cadmium	co.005
alromium	CO.02
Fluoride	2.9
Lead	<0.02
Mercury	CO.001
Nitrates	<0.1
selenium	CO.005
Silver	<0.02
Alkalinity	260
Calcium	8
Chloride	760
Copper	<0.05
Hardness	28
Iron	0.3
Magnesium	7
Manganese	<0.05
PH	8.9
Sodium	810
Sulfate	320
TDS	2180
Zinc	<0.05

Glossary of Water Terms

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

A

Abandoned well—A well whose use has been permanently discontinued or which is in a state of disrepair such that it ca be used for its intended purpose.

Abatement—Reducing the degree or intensity of, or eliminating, pollution.

Acid—A substance that has the ability to react with bases to form salt. The pH of an acidic solution is less than 7. pH 7 is neutral (e.g., pure water)- acids are pH 0 to less than 7. Similarly, bases are greater than 7 to 14. The usual definition of a acid is "any substance that can donate a hydrogen ion".

Acid Deposition ("acid rain")—Water that falls to or condenses on the Earth's surface as rain, drizzle, snow, sleet, hail, dew, frost, or fog with a pH of less than 5.6.

Acidic—The condition of water or soil which contains a sufficient amount of acid substances to lower the pH below 7.0.

Acre-foot (AF)—A common water industry unit of measurement. An acre-foot is 325,851 gallons, or the amount of water needed to cover one acre with water one foot deep. An acre-foot serves annual needs of two typical California families.

Acrylamide (CH2CHCONH2)—An organic monomer used as a starting material for polymers that are used as coagulants or filter aids. Its concentration in finished drinking water is controlled by limiting the allowable dose of polymer that can be added to water.1

The Act—The Metropolitan Water District Act. State legislation signed into law by the governor on May 10, 1927, effective July 29, 1927. Metropolitan incorporated Dec. 6, 1928.

Active Ingredient—The component which kills or otherwise controls, targets pests in any pesticide product. Pesticides ar regulated primarily on the basis of active ingredients.

Adjudication—A court determination of water rights for a groundwater basin or a stream; adjudication sets priorities durir shortages.

Aeration—The addition of air to water or to the pores in soil.

Age Tank—A tank used to store a known concentration of a chemical solution for feed to a chemical feeder. Also known day tank.

Agricultural Pollution—The liquid and solid wastes from farming, including: runoff and leaching of pesticides and fertilize erosion and dust from plowing; animal manure and carcasses; crop residue; and debris.

Algae—Microscopic plants which contain chlorophyll and float or suspend in water. Excess algae growths can impact tas and odors to potable water. Their biological activities affect the pH and dissolved oxygen of the water.

Alkali—Any of certain soluble salts, principally of sodium, potassium, magnesium, and calcium, that have the property of combining with acids from neutral salts and may be used in chemical water treatment processes.

Alkaline—The quality of being bitter due to alkaline content (pH is greater than 7).

Alum (Al2(SO4)3·14 H2O)—The common name for aluminum sulfate, a chemical used in the coagulation process to remove particles from water.1

Aluminum (Al)—A metallic element. Aluminum is the most abundant metal in the earth's crust; it does not occur free in nature. 1

Aqueduct— Man-made canal or pipeline used to transport water.

Aquifer—An underground geologic formation of rock, soil or sediment that is naturally saturated with water; an aquifer stc groundwater.

Arsenic—A naturally occurring element in the environment. Arsenic in drinking water commonly comes from natural sour in the ground, but some can come from industrial pollution. At high concentrations it can cause cancer.

Assay—A test for a particular chemical or effect. 1

B

Bacterium—A microscopic unicellular organism that lacks a nuclear membrane. Some can cause disease.

Bacteria—Plural of bacterium.

Bailer—A 10- to 20-foot-long pipe equipped with a valve at the lower end. It is used to remove slurry from the bottom or tl side of a well as it is being drilled.

Base—A substance that has a pH value between 7 and 14.

Bedrock—The solid rock that underlies all soil, sand, clay, gravel and other loose materials on the earth's surface. Unfractured bedrock is impermeable while fractured bedrock may store and transmit groundwater.

Blackwater—Water that contains animal, human or food wastes.

BMPs—Best management practices. Generally, a set of standardized efficiencies. At Met, refers to a set of water conservation measures agreed to by participants in the California Urban Water Conservation Council.

Bond—A promise to repay money borrowed, plus interest, over a specified period of time.

Bond Issue—A means of raising large amounts of money for major projects by selling bonds.

Brackish—A mixture of freshwater and saltwater.

Buffer—A solution or liquid whose chemical makeup neutralizes acids or bases without a great change in pH.

C

California Environmental Quality Act (CEQA)—Requires an assessment of the possible environmental impacts of proj‹

California Plan—Officially "California's draft Colorado River Water Use Plan," also sometimes called the "4.4 Plan." A planning document designed to reduce California's reliance on surplus Colorado River water over the next 15 years throu conservation, water transfers, and conjunctive use measures.

Call—To order, request or retrieve stored water; to call upon.

Capillarity—The process by which water rises through rock, sediment or soil caused by the cohesion between water molecules and an adhesion between water and other materials that "pulls" the water upward.

CBO—Community-based organization. Local organization with which Metropolitan works on mutually beneficial programs

CUWCC—California Urban Water Conservation Council. Created to increase efficient water use statewide through partnerships among urban water agencies, public interest organizations and private entitites. The Council's goal is to

integrate urban water conservation Best Management Practices into the planning and management of California's water resources.

Centrifuge—A mechanical device that uses centrifugal or rotational forces separate substances of different densities, su(as solids from liquids or liquids from other liquids.

Cesspool—A covered hole or pit for receiving sewage.

CFS—Cubic Feet Per Second.

Chloramination—the treatment of a substance, such as drinking water, with chlorine and ammonia (chloramines) in orde kill disease-causing organisms.

Chloride (Cl–)—One of the major anions commonly found in water and wastewater. Its presence is often determined by ion chromatographic or volumetric analysis. Consumers who drink water with concentrations of chloride exceeding a secondary maximum contaminant level of 250 milligrams per liter may notice a salty taste.1

Chlorination— The treatment of a substance, such as drinking water, with chlorine in order to kill disease-causing organisms.

Chromium—A naturally occurring element found in air, soil, water and food.

Chromium VI—Aka "chrome 6." One of the most common species of chromium, chromium VI is known to cause cancer through exposure to airborne chromium compounds in industrial settings. The evidence of its carcinogenicity by ingestion not compelling. The U.S. Environmental Protection Agency determined that chromium VI was not carcinogenic by ingestic

Clarity—Clearness of liquid, as measured by a variety of methods.1

CII—Metropolitan's water conservation program for commercial, industrial and institutional entities.

Coachella—Coachella Valley Water District. Primarily agricultural irrigation district receiving Colorado River water througl Coachella Canal and serving portions of Riverside, Imperial and San Diego counties north of the Salton Sea. Has priority to California's apportionment of Colorado River water, after (1) PVID; (2.) U.S. Bureau of Reclamation's Yuma Project; (3a Imperial Irrigation District. MWD has fourth priority.

Coagulation—The process, such as in treatment of drinking water, by which dirt and other suspended particles become chemically "stuck together" so they can be removed from water.

Coliform bacteria—Bacteria of the family Enterobacteriaceae, commonly found in the intestinal tracts of warm-blooded animals. In sanitary bacteriology, these organisms are defined as all aerobic and facultative anaerobic, gram-negative, nonspore-forming, rod-shaped bacteria that ferment lactose with gas and acid formation within 48 hours at 95° Fahrenhei (35° Celsius).1

Color—A physical characteristic describing the appearance of water (different from turbidity, which is the cloudiness of water). Color is frequently caused by fulvic and humic acids.1

Combined Sewers—A sewer system that carries both sewage and storm-water runoff.

Condensation—Water vapor changing back into liquid.

Condensation Surfaces—Small particles of matter, such as dust and salt suspended in the atmosphere, which aid the condensation of water vapor in forming clouds.

Confined Aquifer—An aquifer that is bound above and below by dense layers of rock and contains water under pressure

Conjunctive Use—Storing imported water in a local aquifer, in conjunction with groundwater, for later retrieval and use.

Contour Plowing—Plowing done in accordance with the natural outline or shape of the land by keeping the furrows or ditches at the same elevation as much as possible to reduce runoff and erosion.

Control—(1) A condition in which specific quality criteria have been achieved in a laboratory analysis. (2) A type of sampl used to assess the quality of an analytical process.1

Corrosivity—An indication of the corrosiveness of water. The corrosiveness of water is described by the

water's pH, alkalinity, hardness, temperature, total dissolved solids, dissolved oxygen concentration, and Langelier saturation index.1

Cost Effective—Able to at least pay for itself or make a profit.

County Water Authority—A public water district serving a county-wide area.

CRA—Colorado River Aqueduct, built 1933-1941 and owned and operated by the Metropolitan Water District of Southern California.

Cryptosporidium—A group of widespread intestinal coccidian protozoan parasites about 5 micrometers in diameter, causing diarrhea and capable of infecting humans, birds, fish, and snakes. It is responsible for waterborne dise: outbreaks.

CRWUA—Colorado River Water Users Association. CRWUA is a non-profit, non-partisan organization, formed to plan, st formulate and advise on ways to protect and safeguard the interests of all whom use the Colorado River.

CT—The product of disinfectant concentration (in milligrams per liter) determined before or at the first customer and the corresponding disinfectant contact time (in minutes). It is also called the CT value. Units are milligram minutes per liter.1

Cubic foot—A frequent water industry term of measurement, as in cubic feet per second. One cubic foot (cf) equals 7.48 gallons. A cubic foot per second is 450 gallons per minute.

CUWA—California Urban Water Agencies. Group of 11 member agencies serving two-thirds of state's population.

CVP—Central Valley Project. A series of dams, reservoirs and canals in the San Joaquin Valley of California.

Cyst—The infectious stage for Giardia, 7 to 10 micrometers long and refractile to light when viewed with a brightfield microscope.1

D

Delta—Fan-shaped area at the mouth of a river.

Deposition—The process of dropping or getting rid of sediments by an erosional agent such as a river or glacier; also cal sedimentation.

Desalination—The process of removing salt from seawater or brackish water.

Diemer—Robert B. Diemer, Metropolitan general manager 1952-1961, after whom Metropolitan treatment plant at Yorba Linda, in Orange County, was named.

Discharge—the amount of water flowing past a location in a stream/river in a certain amount of time - usually expressed liters per second or gallons per minute.

Disinfectant—An agent that destroys or inactivates harmful microorganisms.

Disinfection By-Product (DBP)—A chemical by-product of the disinfection process. Disinfection by-products are formed the reaction of the disinfectant, natural organic matter, and the bromide ion (Br–). Some disinfection by-products are form through halogen (e.g., chlorine or bromine) substitution reactions; i.e., halogen-substituted by-products are produced. Oth disinfection by-products are oxidation by-products of natural organic matter (e.g., aldehydes—RCHO). Concentrations are typically in the microgram-per-litre or nanogramper-litre range.1

Disinfection By-Product Precursor (DBPP)—A substance that can be converted into a disinfection by-product during disinfection. Typically, most of these precursors are constituents of natural organic matter. In addition, the bromide ion (Br–) is a precursor material. See also bromide; disinfection by-product; natural organic matter.1

Domenigoni—The name of a pioneer family in southwestern Riverside County and of one of the two valleys dammed to create Diamond Valley Lake, Metropolitan's major reservoir near Hemet in southwestern Riverside County.

DRIP—Desalination Research and Innovation Partnership. A landmark research partnership among the water and electric industries, state and federal agencies and academia.

Drought—A prolonged period of below-average precipitation.

DVL—Diamond Valley Lake. Metropolitan's major reservoir near Hemet, in southwestern Riverside County.

DWR—California Department of Water Resources. Guides development and management of California's water resource: owns and operates State Water Project and other water-development facilities.

E

Ecosystem—An interacting network of groups of organisms together with their nonliving or physical environment.

Effluent—Water flowing from a structure such as a treatment plant. Contrast with influent.1Effluent—Water flowing from a structure such as a treatment plant. Contrast with influent.1

EIR—Environmental Impact Report; a state-mandated written summary of the positive and negative effects on the environment caused by the construction and operation of a project.

Endangered Species—A species of animal or plant threatened with extinction.

Epichlorohydrin (chloropropylene oxide, C3H5OCl) —A highly volatile, unstable liquid epoxide. It is a major raw material for epoxy and phenoxy resins and has other industrial uses. It is a treatment chemical that is regulated in drinking water under the Phase II Rule for synthetic organic contaminants and inorganic contaminants.1

Erosion—The processes of picking up, moving, shaping and depositing sediments by various agents; erosional agents include streams, glaciers, wind and gravity.

Escherichia coli (E. coli)—A gram-negative, facultatively anaerobic, nonspore-forming bacillus commonly found in the intestinal tracts of humans and other warm-blooded animals. In sanitary bacteriology, Escherichia coli is considered the primary indicator of recent fecal pollution.1

Evaporation—Water changing into vapor and rising into the air.

F

Fallowing—A program to generate water by paying farmers to fallow land, i.e., not grow crops. The water not used for irrigation is then transferred to urban areas or stored for future use.

Fecal Coliform (FC)—Members of the total coliform group of bacteria that are characterized by their ability to ferment lactose at 112.1° Fahrenheit (44.5° Celsius) and that are considered more specific indicators of fecal contamination than are coliforms that ferment lactose only at 95° Fahrenheit (35° Celsius). Escherichia coli and some Klebsiella pneumoniae strains are the principal fecal coliforms.1

FERC—Federal Energy Regulatory Commission. An independent regulatory agency within the Department of Energy.

Ferric Chloride(FeCl3)—An iron salt used as a coagulant in water treatment. The iron has a valence of +3.1

Filtration—passing water through coal, sand and gravel to remove particles.

Fish Ladder—A device to help fish swim around a dam.

Fishery—The aquatic region in which a certain species of fish lives.

Floc—Clumps of impurities removed from water during the purification process; formed when alum is added to impure wa

Flocculation—A step in water filtration in which alum is added to cause particles to clump together.

Floodplain—Area formed by fine sediments spreading out in the drainage basin on either side of the channel of a river as result of the river's fluctuating water volume and velocity.

Fluoride Ion (F–)—A halide ion. Fluoride salts are added to drinking water for fluoridation. Fluoride is regulated by the US Environmental Protection Agency.1

G

Gene—Aka Gene Camp. Small community on the California bank of the Colorado River, near Parker Dam and Lake Havasu, at and around which are located facilities of Metropolitan's Colorado River Aqueduct. Reputedly the first name of miner who had established "Gene's Camp" at the site.

Giardia—The genus name for a group of single-celled, flagellated, pathogenic protozoas found in a variety of vertebrates, including mammals, birds, and reptiles. These organisms exist either as trophozoites or as cysts, depending on the stage of the life cycle.1

Glacial Striations—Lines carved into rock by overriding ice, showing the direction of glacial movement.

Gross Alpha (a) Particle Activity— The total radioactivity caused by alpha particle emission as inferred from measurements on a dry sample. It is regulated by the US Environmental Protection Agency.1

Gross Beta (b) Particle Activity— The total radioactivity caused by beta particle emission as inferred from measurements a dry sample. It is regulated by the US Environmental Protection Agency.1

Groundwater—Water that has percolated into natural, underground aquifers; water in the ground, not water puddled on t ground.

Groundwater Recharge or Replenishment—Pumping or percolating storm water runoff or imported water into an aquife replenish its supplies.

H

Haloacetic Acid (HAA)—(CX3COOH, where X = Cl, Br, H in various combinations) A class of disinfection by-products formed primarily during the chlorination of water containing natural organic matter. When bromide (Br–) is present, a total nine chlorine-, bromine-and-chlorine-, or bromine-substituted species may be formed. Trihalomethanes and haloacetic ac are the two most prevalent classes of by-products formed during chlorination; and subject to regulation under the Disinfectant/Disinfection by-products rule.1

Hardness—A characteristic of water determined by the levels of calcium and magnesium.

Heterotrophic Plate Count (HPC) —A bacterial enumeration procedure used to estimate bacterial density in an environmental sample, generally water. Other names for the procedure [within the water industry] include total plate cc standard plate count, plate count, and aerobic plate count.1

Hinds—Julian B. Hinds, Metropolitan general manager 1941-1951, after whom the western-most of the five pumping plar along the Colorado River Aqueduct was named.

Hydroelectric Plant—a power plant that produces electricity from the power of rushing water turning turbine-generators.

Hydrology—the scientific study of the behavior of water in the atmosphere, on the Earth's surface and underground.

I

ICP—Innovative Conservation Program. The Innovative Conservation Program portion is designed to provide grants to explore the water savings potential and practicality of new water conserving technologies. Special consideration will be gi to projects promoting water-landscape saving products or technologies.

IICP—Incremental Interruption and Conservation Plan, which was in effect during the state's 1987-92 drought and was replaced by the WSDM Plan.

IID—Imperial Irrigation District, primarily agricultural irrigation district in Imperial County south of the Salton Sea. Has prioı 3(a) to California's apportionment of Colorado River water. Coachella has priority 3(b). MWD has fourth.

Immunofluorescence—The emission of visible light by a compound that has been irradiated with ultraviolet light. For example, a fluorescent compound (i.e., a fluorescein) can be attached to an antibody. Bacterial, viral, or other antigens that react with the antibody can then be observed by illuminating the sample with ultraviolet light.1

I/O—Inlet-outlet facility at a reservoir.

Inorganic—Pertaining to material such as sand, salt, iron, calcium salts, and other mineral materials. Inorganic substances are of mineral origin, whereas organic substances are usually of animal or plant origin and contain carbon.1

IRP—Integrated Resources Plan. The district's plan to ensure reliable water delivery to its customer member agencies despite population growth, dry spells and droughts. The IRP resources mix includes water storage, conservation, best management practices (BMPs), recycling, desalination, and groundwater recovery, among others.

Irrigation—Supplying water to agriculture by artificial means, such as pumping water onto crops in an area where rainfall insufficient.

ISP—Innovated Supply Program. The ISP will provide up to a total of $250,000 in grants on a competitive basis to stimula and advance new innovative ideas that have potential to produce new sources of water supply for Southern Califoma.

J

Jensen—Joseph Jensen, Metropolitan board chairman 1949-1974, after whom the Metropolitan treatment plant at Grana Hills, in Los Angeles County, was named.

L

Laguna Declaration—A Dec. 16, 1952 policy statement by Metropolitan's Board of Directors that it will "provide its servic area with adequate supplies of water to meet expanding and increasing needs in the years ahead."

Law of the River—A complex body of laws, court decrees, contracts, agreements, regulations and an international treaty used to govern allocation and management of Colorado River water.

Leach—To remove components from the soil by the action of water trickling through.

Legionella—A genus of bacteria of the family Legionellaceae. It currently consists of at least 51 serogroups comprising 3 species.1 It has the ability to colonize water in distribution systems (heating tanks, cooling towers, air conditioning lines, e It can cause disease in humans (e.g., Legionnaires' disease or Legionellosis) that is progressive and sometimes fatal, or milder form of pneumonic illness (Pontiac fever) that is self-limited (i.e., heals on its own) with respiratory symptoms simil influenza.

M

MAF—Million acre-feet.

Marginal Land—Land which, in its natural state, is not well suited for a particular purpose, such as raising crops.

MCL—Maximum Contaminant Level. According to health agencies, the maximum amount of a substance that can be pre in water that's safe to drink and which looks, tastes and smells good.

Member Agency—One of 26 member public water providers associated with the Metropolitan Water District of Southern California, from which it purchases water and on whose board it is represented.

MGD—Million gallons per day, a measure used for water treatment plants and other facilities.

Microbiological—Relating to microorganisms and their life processes.1

Microorganism—An organism of microscopic size, such as bacterium.

Mills—Henry J. Mills, Metropolitan general manager 1967-1971, after whom Metropolitan treatment plant at Riverside wa named.

Mitigation—A way in which an agency may offset negative environmental impacts of a project or make the impacts less serious.

Moab—A site near Moab, Utah, where a 10.5 million ton mountain of uranium mill tailings (scrap) is leaching pollutants, including uranium, into the nearby Colorado River.

Monterey Agreement—A December 1994 statement of principles to settle disputes over water allocations and operation

aspects of the State Water Project, providing greater water management flexibility and financial stability.

MTBE—Methyl tertiary butyl ether. An oxygenate used in California gasoline to help prevent air pollution. The chemical hε long life and has been determined to have polluted lakes, reservoirs and groundwater after leaking from watercraft, underground tanks and pipelines. Required to be phased out by Dec. 31, 2002.

Mulch—Material spread on the ground to reduce soil erosion and evaporation of water; include hay, plastic sheeting and wood chips.

Municipal Water District—A public water provider governed by a locally elected board of directors, which supplies water the public directly or through subagencies.

MWQI—Municipal Water Quality Investigation. Government agencies conduct water quality studies in the Sacramento watershed, the Sacramento-San Joaquin Delta, and the San Francisco Bay Area.

N

Natural Environment—All living and nonliving things that occur naturally on the earth.

Nitrate (NO_3^-)—An oxidized ion of nitrogen. Nitrifying bacteria can convert nitrite (NO_2^-) to nitrate in the nitrogen cycle. Sodium nitrate ($NaNO_3$) and potassium nitrate (KNO_3) are used as fertilizer. The nitrate ion is regulated by the US Environmental Protection Agency.[1]

Nitrite (NO_2^-)—An intermediate oxidized ion of nitrogen. Nitrifying bacteria can convert ammonia (NH_3) to nitrite (NO_2^-) nitrate (NO_3^-) in the nitrogen cycle. Sodium nitrite ($NaNO_2$) is used in curing meats. The nitrite ion is regulated by the US Environmental Protection Agency.[1]

Nonpoint Source Pollution—Pollution which comes from diffuse sources such as urban and agricultural runoff.

NWRA—National Water Resources Association. Advocates federal policies, legislation and regulations promoting the development, management, protection and beneficial use of water resources.

O

Odor Threshold—The minimum odor of a water sample that can just be detected after successive dilutions with odorless water.[1] The odor threshold is reported as the threshold odor number.

Oocyst—A structure that is produced by [some] coccidian protozoa (i.e., Cryptosporidium) as a result of sexual reproduction during the life cycle. The oocyst is usually the infectious and environmental stage, and it contains sporozoites. For the enteric protozoa, the oocyst is excreted in the feces.[1]

Organic Chemical—A chemical having a carbon–hydrogen structure.[1]

Ozone—A gas derived from oxygen that is bubbled through water during the treatment processes to kill microorganisms.

P

Palo Verde—Palo Verde Irrigation District, PVID; primarily agricultural irrigation district lying along the Colorado River 11(miles north of Mexico. Has first priority to river water from California's apportionment. MWD has fourth priority.

Parameter—A water quality attribute. For example, the presence of certain bacteria, the hardness, and the level of sodium are all parameters.[1]

Pathogen—an infectious agent. An organism capable of causing infection or infectious disease.[1]

Perchlorate—A chemical used in manufacturing rocket fuel that has contaminated some Southern California groundwate basins. Perchlorate interferes with the iodide uptake into the thyroid gland. The disruption of thyroid functions leads to changes in metabolism in adults and normal growth and development in children.

Perennial Yield—Maximum quantity of water that can be annually withdrawn from a groundwater basin over a long perio time (during which water supply conditions approximate average conditions) without developing an overdraft condition.

PEROXONE—A combination of peroxide and ozone used to kill germs and oxidize taste-and-odor compounds in water.

pH—A relative scale of how acidic or basic (alkaline) a material is; the scale goes from 0 to 14; 7 is neutral, acids have pH values less than 7 and bases have pH values higher than 7.

Pipeline—Carries water above or underground to homes and businesses.

Potable—Drinkable water. Nonpotable means nondrinkable.

Preferential Rights—A member agency has a preferential right to a percentage of Metropolitan's available water supply based on a formula established by the Legislature and set forth in Section 135 of the Metropolitan Act. That percentage is equal to the ratio of each member agency's total accumulated payments to Metropolitan's capital costs and operating expenses compared to the total of all member agencies' payments towards those costs, specifically excepting payments f the purchase of water. The Preferential Rights section has never been invoked.

Protozoan—Single-celled, animal-like, eukaryotic organisms of the kingdom Protista. Protozoans can occur wherever moisture exists. There are many parasites and commensals of plants and animals, as well as free-living species. They ca a number of diseases, such as African sleeping sickness, malaria, and dysentery. They are an economically and scientific important group. It is thought that the organisms of the kingdom Animalia evolved from ancestors which were protozoans.

Pumping Lift—Distance water must be lifted in a well from the pumping level to the ground surface.

Pumping Plant—Facility that lifts water up and over the hills.

Q

Quantification—Refers to Quantification Settlement Agreement, a proposed agreement among MWD, CVWD and IID to settle a variety of long-standing disputes regarding the priority, use and transfer of Colorado River water within California.

R

Radionuclide—A material with an unstable atomic nucleus that spontaneously decays or disintegrates, producing radiation.[1]

Radium (Ra)—A naturally occurring radioactive element (in the form of radium-226 or radium-228) created in the decay of the uranium and thorium series. Radium can be removed from water by cation exchange softening.[1]

Radium-226 + Radium-228 (Ra-226 + Ra-228)—The sum of the naturally occurring radioactive isotopes of radium. The regulation for radium by the US Environmental Protection Agency is for the sum of the [two] isotopes.[1]

Recharge—Replenishing an aquifer with stormwater or imported water

Reclaimed Water—Wastewater that has been cleaned so that it can be reused for most purposes except drinking.

Reclamation—Historically, a wide-ranging federal program to irrigate arid lands throughout the West. More recently, a euphemism for treating sewage water so it can be reused for nonpotable purposes. See recycled.

Recycled—Wastewater cleaned for re-use, usually for nonpotable purposes such as irrigating landscape and refilling aquifers.

Reservoirs—A pond or lake where water is collected and stored until it is needed.

Residuals—Any gaseous, liquid, or solid by-product of a treatment process that ultimately must be disposed of. For example, in a fixed-bed filter for removing particles from water, both the filter backwash water and the solids in the backwash water are residuals.[1]

Rills—Small grooves, furrows, or channels in soil made by water flowing down over its surface; also another name for a stream-usually a small stream.

Runoff—Liquid water that travels over the surface of the Earth, moving downward due to the law of gravity; runoff is one ' in which water that falls as precipitation returns to the ocean.

RUWMP—Regional Urban Water Management Plan. State law requires that every urban water retailer and wholesaler prepare and adopt a water management plan every five years. A dictionary of MWD programs, projects and terminology.

S

SCAG—Southern California Association of Governments. It has evolved as the largest of nearly 700 councils of governm in the United States, functioning as the Metropolitan Planning Organization for six counties. As the designated Metropolita Planning Organization, the Association of Governments is mandated by the federal government to research and draw up plans for transportation, growth management, hazardous waste management and air quality. Additional mandates exist at state level.

Salinity—The scaling or white deposits that accumulate on coffee pots, water heaters and plumbing fixtures resulting fror dissolved mineral salts in the water. Also known as total dissolved solids or TDS.

Skinner—Robert A. Skinner, Metropolitan general manager 1962-1967, after whom Metropolitan treatment plant near Winchester, in southwestern Riverside County, was named.

Source water— The supply of water for a water utility. Source water is usually treated before distribution to consumers, but some groundwaters are of such a quality that they can be distributed untreated. This term is preferred over raw water.1

Specific Conductance—A measure of the ability of a solution to conduct electrical current. Its value is inversely proportional to the solution's electrical resistance. The conductivity value is commonly used in water-desalting processes as a means to evaluate desalting efficiency and to estimate the total dissolved solids concentration; the conductivity value of a water sample is multiplied by an empirical factor representative of the typical total dissolved solids/conductivity ratio for the specific type of water. The units of conductivity are often reported as micromhos per centimetre at 25° Celsius, but this is not a Systême International unit; multiplying such a value by 10–4 converts the value to units of siemens per meter.1

Standard—(1) A recommended practice in the manufacturing of products or materials or in the conduct of a business, art, or profession. Such standards may or may not be used as (or called) specifications. (2) A document that specifies the minimum acceptable characteristics of a product or material, issued by an organization that develops such documents (e.g., an American Water Works Association standard). (3) A numerical contaminant limit set by a regulatory agency (e.g., a US Environmental Protection Agency maximum contamina level).1

Strategic Plan—The product of a strategic planning process, a comprehensive approach to how Metropolitan does busin The plan's components include a composite rate structure, a resource management plan, the determination of prices and compatible board governance and management structure with comprehensive ethical standards.

Sulfate (SO42–)—An inorganic ion that is widely distributed in nature. It may be present in natural waters in concentrations ranging from a few to several thousand milligrams per liter.1

Surface Runoff—Water flowing along the ground into rivers, lakes and oceans.

Surface Water—All water, fresh and salty, on the Earth's surface.

SWP—State Water Project, of which Metropolitan Water District is the largest contractor. Owned and operated by the California Department of Water Resources.

SWRCB—State Water Resources Conrol Board. Regulates water quality and water rights to protect beneficial water use i the Bay/Delta estuary.

T

THMLs—Total trihalomethanes. By-products of chlorination.

Topsoil—The top layer of soil; topsoil can grow better crops partly because it has more organic matter (humus), allowing hold more water than lower soil layers.

Total Chlorine Residual—The total amount of chlorine residual present after a given contact time in a water sample, regardless of the type of chlorine. See also residual chlorine; total chlorine.1

Total Coliform Rule (TCR)—A rulemaking of the US Environmental Protection Agency that sets National Primary Drinking Water Regulations for total coliforms, fecal coliforms, and Escherichia coli. The rule was promulgated Ju 29, 1989 (54 Federal Register 27544–27568) and amended Jan. 15, 1991 (56 Federal Register 1556–1557).1

Total Coliforms (TC)—The group of bacteria used as warm-blooded animal fecal pollution indicator organisms of drinking water quality. Total coliforms are regulated by the US Environmental Protection Agency.1

Total Dissolved Solids (TDS) —The weight per unit volume of filtered water. The liquid passing the filter are evaporated dryness. The filter pore diameter and evaporation temperature are frequently specified.

Total Organic Carbon (TOC)—A measure of the concentration of organic carbon in water, determined by oxidation of the organic matter into carbon dioxide (CO_2). TOC includes all the carbon atoms covalently bonded in organi molecules. Most of the organic carbon in drinking water supplies is dissolved organic carbon, with the remainder referred as particulate organic carbon. In natural waters, total organic carbon is composed primarily of nonspecific humic materials Total organic carbon is used as a surrogate measurement for disinfection by-product precursors, although only a small fraction of the organic carbon will react to form these by-products. Quantitatively, total organic carbon is determined by removing interfering inorganic carbon, such as bicarbonate (HCO_3^-), and oxidizing the organic carbon to carbon dioxide. Typically, the carbon dioxide is then measured with a nondispersive infrared detector.1

Total Trihalomethanes (TTHM) —The sum of the four chlorine and bromine-containing trihalomethanes (i.e., chloroform, bromodichloromethane, dibromochloromethane, and bromoform). The US Environmental Protection Agency regulates the sum of these four species on a weight concentration basis.1

Transpiration—Evaporation of water through the leaves of plants.

Trihalomethanes—Organic compounds which may be harmful to health at certain levels in drinking water.

Turbidity—The state of having sediment or foreign particles suspended or stirred up in water.

U

ULF—Ultra-low-flow, as in water-saving toilet fixtures. Currently ULF toilets use 1.6 gallons per flush.

Unconfined Aquifer—An aquifer that discharges and recharges with an upper surface that is the water table.

Uranium (U) —A metallic element that is naturally occurring with three main radioactive isotopes (i.e., U-234, U-235, and 238). Uranium is carcinogenic and can also cause damage to the kidney. Total uranium is regulated by the US Environme Protection Agency.

Usable Storage Capacity—The quanitity of groundwater of acceptable quality that can be economically withdrawn from storage.

USBR—United States Bureau of Reclamation.

UWI—Urban Water Institute. This organization provides programs and publications geared to policy makers who can no longer afford to be uninformed on water, wastewater, flood control, runoff and environmental issues.

V

Virus—(1) A minute organism not visible by light microscopy. A virus is an obligate parasite dependent on nutrients inside cells for its metabolic and reproductive needs. It consists of a strand of either deoxyribonucleic acid or ribonucleic acid, but not both, [inside] a protein covering called a capsid.1

W

Wadsworth—Hiram W. Wadsworth, prominent Pasadena proponent of building an aqueduct to urban Southern Californi from the Colorado River and a founder of the Metropolitan Water District, after whom the pumping plant at Diamond Valle Lake was named.

Wash Water—Water that is used to clean a unit process. Wash water is typically identified as backwash water and is associated with the wastewater resulting from the cleaning of filter media to remove attached particles.1

Wastewater—Water that has waste material in it.

Water Cycle—The movement of water from the air to and below the Earth's surface and back into the air.

Water Reclamation—Treating wastewater so that it can be used again.

Watershed—A geographical portion of the Earth's surface from which water drains or runs off to a single place like a rivel also called a drainage area.

Weymouth—F.E. Weymouth, Metropolitan's first chief engineer and general manager, 1929-41; after whom Metropolitan first treatment plant at La Verne, in Los Angeles County, was named.

WSDM Plan—Water Surplus and Drought Management Plan, developed by Metropolitan and its member agencies in 19 and 1999, and adopted by the board in April 1999. Replaced IICP. Identifies the expected sequence of resource management actions Metropolitan will take during surpluses and shortages.

X

xeriscape - landscaping that doesn't require a lot of water

Z

zanja - Spanish word for ditch
zone of aeration - the portion of the ground from the Earth's surface down to the water table - the zone of aeration is not saturated with water because its pores are filled partly by air and partly by water.
zone of saturation - the portion of the ground below the water table where all the pores in rock, sediment, and soil are fill with water

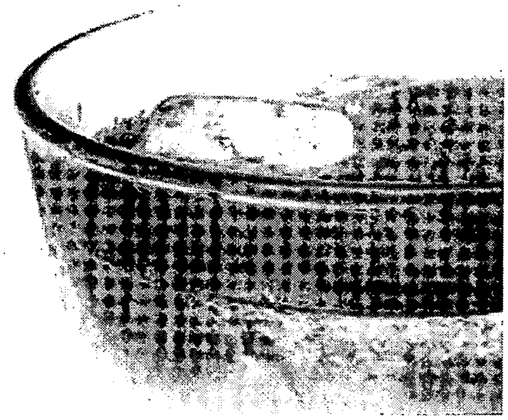
U.S. Environmental Protection Agency

Ground Water & Drinking Water

List of Drinking Water Contaminants & MCLs

National Primary Drinking Water Regulations

National Primary Drinking Water Regulations (NPDWRs or primary standards) are legally enforceable standards that apply to public water systems. Primary standards protect public health by limiting the levels of contaminants in drinking water. Visit the list of regulated contaminants with links for more details.



- List of Contaminants & their Maximum Contaminant Level (MCLs)
- Setting Standards for Safe Drinking Water to learn about EPA's standard-setting process
- EPA's Regulated Contaminant Timeline (86 K PDF FILE, 1 pg) (ALL ABOUT PDF FILES)
- National Primary Drinking Water Regulations EXIT disclaimer - The complete regulations regarding these contaminants availible from the Code of Federal Regulations Website

National Secondary Drinking Water Regulations

National Secondary Drinking Water Regulations (NSDWRs or secondary standards) are non-enforceable guidelines regulating contaminants that may cause cosmetic effects (such as skin or tooth discoloration) or aesthetic effects (such as taste, odor, or color) in drinking water. EPA recommends secondary standards to water systems but does not require systems to comply. However, states may choose to adopt them as enforceable standards.

- List of National Secondary Drinking Water Regulations
- National Secondary Drinking Water Regulations EXIT disclaimer - The complete regulations regarding these contaminants availible from the Code of Federal Regulations Web Site.

Unregulated Contaminants

This list of contaminants which, at the time of publication, are not subject to any proposed or promulgated national primary drinking water regulation (NPDWR), are known or anticipated to occur in public water systems, and may require regulations under SDWA. For more information check out the list, or vist the Drinking Water Contaminant Candidate List (CCL) web site.

- Drinking Water Contaminant Candidate List 2

- Drinking Water Contaminant Candidate List (CCL) Web Site
- Unregulated Contaminant Monitoring Program (UCM)

List of Contaminants & their MCLs

EPA 816-F
Ju

Microorganisms | Disinfectants | Disinfection Byproducts | Inorganic Chemicals | Orga
Chemicals | Radionuclides

- The links provided below are to either Consumer Fact Sheet, Rule Implementation sites, or PDF files (ALL ABOUT PDF FILES)
- Alphabetical Version of this chart in PDF format EPA 816-F-03-016 June 2003 (396 K FILE) (ALL ABOUT PDF FILES)

Microorganisms

Contaminant	MCLG[1] (mg/L)[2]	MCL or TT[1] (mg/L)[2]	Potential Health Effects from Ingestion of Water	Sources of Contaminant i Drinking Wate
Cryptosporidium (pdf file)	zero	TT [3]	Gastrointestinal illness (e.g., diarrhea, vomiting, cramps)	Human and fec animal waste
Giardia lamblia	zero	TT[3]	Gastrointestinal illness (e.g., diarrhea, vomiting, cramps)	Human and ani fecal waste
Heterotrophic plate count	n/a	TT[3]	HPC has no health effects; it is an analytic method used to measure the variety of bacteria that are common in water. The lower the concentration of bacteria in drinking water, the better maintained the water system is.	HPC measures range of bacter that are natural present in the environment
Legionella	zero	TT[3]	Legionnaire's Disease, a type of pneumonia	Found naturally water; multiplie heating system
Total Coliforms (including fecal coliform and *E. Coli*)	zero	5.0%[4]	Not a health threat in itself; it is used to indicate whether other potentially harmful bacteria may be present[5]	Coliforms are naturally preser the environmer well as feces; fe coliforms and E only come from human and ani fecal waste.
Turbidity	n/a	TT[3]	Turbidity is a measure of the cloudiness of water. It is used to indicate water quality and filtration effectiveness (e.g., whether disease-causing organisms are present). Higher turbidity levels are	Soil runoff

			often associated with higher levels of disease-causing microorganisms such as viruses, parasites and some bacteria. These organisms can cause symptoms such as nausea, cramps, diarrhea, and associated headaches.	
Viruses (enteric)	zero	TT[3]	Gastrointestinal illness (e.g., diarrhea, vomiting, cramps)	Human and ani fecal waste

Disinfection Byproducts

Contaminant	MCLG[1] (mg/L)[2]	MCL or TT[1] (mg/L)[2]	Potential Health Effects from Ingestion of Water	Sources of Contaminant i Drinking Wate
Bromate	zero	0.010	Increased risk of cancer	Byproduct of drinking water disinfection
Chlorite	0.8	1.0	Anemia; infants & young children: nervous system effects	Byproduct of drinking water disinfection
Haloacetic acids (HAA5)	n/a[6]	0.060	Increased risk of cancer	Byproduct of drinking water disinfection
Total Trihalomethanes (TTHMs)	none[7] ---------- n/a[6]	0.10 --------- - 0.080	Liver, kidney or central nervous system problems; increased risk of cancer	Byproduct of drinking water disinfection

Disinfectants

Contaminant	MRDLG[1] (mg/L)[2]	MRDL[1] (mg/L)[2]	Potential Health Effects from Ingestion of Water	Sources of Contaminant ir Drinking Water
Chloramines (as Cl_2)	MRDLG=4[1]	MRDL=4.0[1]	Eye/nose irritation; stomach discomfort, anemia	Water additive u to control microl
Chlorine (as Cl_2)	MRDLG=4[1]	MRDL=4.0[1]	Eye/nose irritation; stomach discomfort	Water additive u to control microl
Chlorine dioxide (as ClO_2)	MRDLG=0.8[1]	MRDL=0.8[1]	Anemia; infants & young children: nervous system effects	Water additive u to control microl

Inorganic Chemicals

Contaminant	MCLG[1] (mg/L)[2]	MCL or TT[1] (mg/L)[2]	Potential Health Effects from Ingestion of Water	Sources of Contaminant in Drinking Water
Antimony	0.006	0.006	Increase in blood cholesterol; decrease in blood sugar	Discharge from petroleum refinerie fire retardants; ceramics; electroni solder
Arsenic	0[7]	0.010 as of 01/23/06	Skin damage or problems with circulatory systems, and may have increased risk of getting cancer	Erosion of natural deposits; runoff fro orchards, runoff frc glass & electronicsproducti wastes
Asbestos (fiber >10 micrometers)	7 million fibers per liter	7 MFL	Increased risk of developing benign intestinal polyps	Decay of asbestos cement in water m: erosion of natural deposits
Barium	2	2	Increase in blood pressure	Discharge of drillin wastes; discharge metal refineries; er of natural deposits
Beryllium	0.004	0.004	Intestinal lesions	Discharge from me refineries and coal burning factories; discharge from electrical, aerospa and defense indus
Cadmium	0.005	0.005	Kidney damage	Corrosion of galva pipes; erosion of n deposits; discharg from metal refineri runoff from waste batteries and paint
Chromium (total)	0.1	0.1	Allergic dermatitis	Discharge from ste and pulp mills; ero: of natural deposits
Copper	1.3	TT[8]; Action Level=1.3	Short term exposure: Gastrointestinal distress Long term exposure: Liver or kidney damage People with Wilson's Disease should consult their personal doctor if the amount of copper in their water exceeds the	Corrosion of house plumbing systems; erosion of natural deposits

			action level	
Cyanide (as free cyanide)	0.2	0.2	Nerve damage or thyroid problems	Discharge from steel/metal factorie discharge from pla and fertilizer factor
Fluoride	4.0	4.0	Bone disease (pain and tenderness of the bones); Children may get mottled teeth	Water additive whi promotes strong te erosion of natural deposits; discharg from fertilizer and aluminum factories
Lead	zero	TT[8]; Action Level=0.015	Infants and children: Delays in physical or mental development; children could show slight deficits in attention span and learning abilities Adults: Kidney problems; high blood pressure	Corrosion of house plumbing systems; erosion of natural deposits
Mercury (inorganic)	0.002	0.002	Kidney damage	Erosion of natural deposits; discharg from refineries and factories; runoff fro landfills and cropla
Nitrate (measured as Nitrogen)	10	10	Infants below the age of six months who drink water containing nitrate in excess of the MCL could become seriously ill and, if untreated, may die. Symptoms include shortness of breath and blue-baby syndrome.	Runoff from fertiliz use; leaching from septic tanks, sewa erosion of natural deposits
Nitrite (measured as Nitrogen)	1	1	Infants below the age of six months who drink water containing nitrite in excess of the MCL could become seriously ill and, if untreated, may die. Symptoms include shortness of breath and blue-baby syndrome.	Runoff from fertiliz use; leaching from septic tanks, sewa erosion of natural deposits
Selenium	0.05	0.05	Hair or fingernail loss; numbness in fingers or toes; circulatory problems	Discharge from petroleum refinerie erosion of natural deposits; discharg from mines
Thallium	0.0005	0.002	Hair loss; changes in	Leaching from ore-

			blood; kidney, intestine, or liver problems	processing sites; discharge from electronics, glass, drug factories

Organic Chemicals

Contaminant	MCLG[1] (mg/L) [2]	MCL or TT[1] (mg/L)[2]	Potential Health Effects from Ingestion of Water	Sources of Contaminant Drinking Wat
Acrylamide	zero	TT[9]	Nervous system or blood problems; increased risk of cancer	Added to wate during sewage/waste treatment
Alachlor	zero	0.002	Eye, liver, kidney or spleen problems; anemia; increased risk of cancer	Runoff from herbicide usec row crops
Atrazine	0.003	0.003	Cardiovascular system or reproductive problems	Runoff from herbicide usec row crops
Benzene	zero	0.005	Anemia; decrease in blood platelets; increased risk of cancer	Discharge fror factories; leacl from gas stora tanks and lanc
Benzo(a)pyrene (PAHs)	zero	0.0002	Reproductive difficulties; increased risk of cancer	Leaching from linings of wate storage tanks distribution lin
Carbofuran	0.04	0.04	Problems with blood, nervous system, or reproductive system	Leaching of sc fumigant used rice and alfalfa
Carbon tetrachloride	zero	0.005	Liver problems; increased risk of cancer	Discharge fror chemical plant and other indu activities

Chlordane	zero	0.002	Liver or nervous system problems; increased risk of cancer	Residue of bai termiticide
Chlorobenzene	0.1	0.1	Liver or kidney problems	Discharge fror chemical and agricultural chemical facto
2,4-D	0.07	0.07	Kidney, liver, or adrenal gland problems	Runoff from herbicide usec row crops
Dalapon	0.2	0.2	Minor kidney changes	Runoff from herbicide usec rights of way
1,2-Dibromo-3-chloropropane (DBCP)	zero	0.0002	Reproductive difficulties; increased risk of cancer	Runoff/leachin from soil fumiç used on soybe cotton, pineap and orchards
o-Dichlorobenzene	0.6	0.6	Liver, kidney, or circulatory system problems	Discharge fror industrial chen factories
p-Dichlorobenzene	0.075	0.075	Anemia; liver, kidney or spleen damage; changes in blood	Discharge fror industrial chen factories
1,2-Dichloroethane	zero	0.005	Increased risk of cancer	Discharge fror industrial chen factories
1,1-Dichloroethylene	0.007	0.007	Liver problems	Discharge fror industrial chen factories
cis-1,2-Dichloroethylene	0.07	0.07	Liver problems	Discharge fror industrial chen factories
trans-1,2-Dichloroethylene	0.1	0.1	Liver problems	Discharge fror industrial chen factories
Dichloromethane	zero	0.005	Liver problems; increased risk of cancer	Discharge fror drug and chen factories

1,2-Dichloropropane	zero	0.005	Increased risk of cancer	Discharge fror industrial chen factories
Di(2-ethylhexyl) adipate	0.4	0.4	Weight loss, liver problems, or possible reproductive difficulties.	Discharge fror chemical facto
Di(2-ethylhexyl) phthalate	zero	0.006	Reproductive difficulties; liver problems; increased risk of cancer	Discharge fror rubber and chemical facto
Dinoseb	0.007	0.007	Reproductive difficulties	Runoff from herbicide usec soybeans and vegetables
Dioxin (2,3,7,8-TCDD)	zero	0.00000003	Reproductive difficulties; increased risk of cancer	Emissions fror waste incinera and other combustion; discharge fron chemical facto
Diquat	0.02	0.02	Cataracts	Runoff from herbicide use
Endothall	0.1	0.1	Stomach and intestinal problems	Runoff from herbicide use
Endrin	0.002	0.002	Liver problems	Residue of bai insecticide
Epichlorohydrin	zero	TT[9]	Increased cancer risk, and over a long period of time, stomach problems	Discharge fror industrial chen factories; an impurity of sor water treatmei chemicals
Ethylbenzene	0.7	0.7	Liver or kidneys problems	Discharge fror petroleum refineries
Ethylene dibromide	zero	0.00005	Problems with liver, stomach, reproductive system, or kidneys; increased risk of cancer	Discharge fror petroleum refineries
Glyphosate	0.7	0.7	Kidney problems;	Runoff from herbicide use

			reproductive difficulties	
Heptachlor	zero	0.0004	Liver damage; increased risk of cancer	Residue of bai termiticide
Heptachlor epoxide	zero	0.0002	Liver damage; increased risk of cancer	Breakdown of heptachlor
Hexachlorobenzene	zero	0.001	Liver or kidney problems; reproductive difficulties; increased risk of cancer	Discharge fror metal refinerie agricultural chemical facto
Hexachlorocyclopentadiene	0.05	0.05	Kidney or stomach problems	Discharge fror chemical facto
Lindane	0.0002	0.0002	Liver or kidney problems	Runoff/leachin from insecticid used on cattle lumber, gardei
Methoxychlor	0.04	0.04	Reproductive difficulties	Runoff/leachin from insecticid used on fruits, vegetables, alf livestock
Oxamyl (Vydate)	0.2	0.2	Slight nervous system effects	Runoff/leachin from insecticid used on apple potatoes, and tomatoes
Polychlorinated biphenyls (PCBs)	zero	0.0005	Skin changes; thymus gland problems; immune deficiencies; reproductive or nervous system difficulties; increased risk of cancer	Runoff from landfills; disch: of waste chem
Pentachlorophenol	zero	0.001	Liver or kidney problems; increased cancer risk	Discharge fror wood preservi factories
Picloram	0.5	0.5	Liver problems	Herbicide runc
Simazine	0.004	0.004	Problems with	Herbicide runc

			blood	
Styrene	0.1	0.1	Liver, kidney, or circulatory system problems	Discharge fror rubber and plɛ factories; leacl from landfills
Tetrachloroethylene	zero	0.005	Liver problems; increased risk of cancer	Discharge fror factories and (cleaners
Toluene	1	1	Nervous system, kidney, or liver problems	Discharge fror petroleum fact
Toxaphene	zero	0.003	Kidney, liver, or thyroid problems; increased risk of cancer	Runoff/leachin from insecticid used on cottor cattle
2,4,5-TP (Silvex)	0.05	0.05	Liver problems	Residue of bai herbicide
1,2,4-Trichlorobenzene	0.07	0.07	Changes in adrenal glands	Discharge fror textile finishinç factories
1,1,1-Trichloroethane	0.20	0.2	Liver, nervous system, or circulatory problems	Discharge fror metal degreas sites and othe factories
1,1,2-Trichloroethane	0.003	0.005	Liver, kidney, or immune system problems	Discharge fror industrial chen factories
Trichloroethylene	zero	0.005	Liver problems; increased risk of cancer	Discharge fror metal degreas sites and othe factories
Vinyl chloride	zero	0.002	Increased risk of cancer	Leaching from pipes; dischar(from plastic factories
Xylenes (total)	10	10	Nervous system damage	Discharge fror petroleum fact discharge fron chemical facto

Radionuclides

Contaminant	MCLG[1] (mg/L)[2]	MCL or TT[1] (mg/L)[2]	Potential Health Effects from Ingestion of Water	Sources of Contaminant in Drinking Water
Alpha particles	none[7] --------- zero	15 picocuries per Liter (pCi/L)	Increased risk of cancer	Erosion of natur deposits of certa minerals that are radioactive and emit a form of radiation known alpha radiation
Beta particles and photon emitters	none[7] --------- zero	4 millirems per year	Increased risk of cancer	Decay of natura man-made depc certain minerals are radioactive a may emit forms radiation known photons and bet radiation
Radium 226 and Radium 228 (combined)	none[7] --------- zero	5 pCi/L	Increased risk of cancer	Erosion of natur deposits
Uranium	zero	30 ug/L as of 12/08/03	Increased risk of cancer, kidney toxicity	Erosion of natur deposits

Notes

[1] Definitions:
Maximum Contaminant Level (MCL) - The highest level of a contaminant that is allowec drinking water. MCLs are set as close to MCLGs as feasible using the best available treat technology and taking cost into consideration. MCLs are enforceable standards.
Maximum Contaminant Level Goal (MCLG) - The level of a contaminant in drinking wat below which there is no known or expected risk to health. MCLGs allow for a margin of sa and are non-enforceable public health goals.
Maximum Residual Disinfectant Level (MRDL) - The highest level of a disinfectant allo drinking water. There is convincing evidence that addition of a disinfectant is necessary fc control of microbial contaminants.
Maximum Residual Disinfectant Level Goal (MRDLG) - The level of a drinking water disinfectant below which there is no known or expected risk to health. MRDLGs do not ref the benefits of the use of disinfectants to control microbial contaminants.
Treatment Technique - A required process intended to reduce the level of a contaminan drinking water.

[2] Units are in milligrams per liter (mg/L) unless otherwise noted. Milligrams per liter are equivalent to parts per million.

[3] EPA's surface water treatment rules require systems using surface water or ground wat under the direct influence of surface water to (1) disinfect their water, and (2) filter their wa meet criteria for avoiding filtration so that the following contaminants are controlled at the following levels:

- *Cryptosporidium:* (as of1/1/02 for systems serving >10,000 and 1/14/05 for system serving <10,000) 99% removal.
- *Giardia lamblia:* 99.9% removal/inactivation

- Viruses: 99.99% removal/inactivation
- *Legionella:* No limit, but EPA believes that if *Giardia* and viruses are removed/inact *Legionella* will also be controlled.
- Turbidity: At no time can turbidity (cloudiness of water) go above 5 nephelolometric turbidity units (NTU); systems that filter must ensure that the turbidity go no higher NTU (0.5 NTU for conventional or direct filtration) in at least 95% of the daily samp any month. As of January 1, 2002, turbidity may never exceed 1 NTU, and must nc exceed 0.3 NTU in 95% of daily samples in any month.
- HPC: No more than 500 bacterial colonies per milliliter.
- Long Term 1 Enhanced Surface Water Treatment (Effective Date: January 14, 200 Surface water systems or (GWUDI) systems serving fewer than 10,000 people mu comply with the applicable Long Term 1 Enhanced Surface Water Treatment Rule provisions (e.g. turbidity standards, individual filter monitoring, *Cryptosporidium* rer requirements, updated watershed control requirements for unfiltered systems).
- Filter Backwash Recycling; The Filter Backwash Recycling Rule requires systems recycle to return specific recycle flows through all processes of the system's existir conventional or direct filtration system or at an alternate location approved by the s

[4] more than 5.0% samples total coliform-positive in a month. (For water systems that colle fewer than 40 routine samples per month, no more than one sample can be total coliform- positive per month.) Every sample that has total coliform must be analyzed for either feca coliforms or *E. coli* if two consecutive TC-positive samples, and one is also positive for *E.* fecal coliforms, system has an acute MCL violation.

[5] Fecal coliform and *E. coli* are bacteria whose presence indicates that the water may be contaminated with human or animal wastes. Disease-causing microbes (pathogens) in th wastes can cause diarrhea, cramps, nausea, headaches, or other symptoms. These path may pose a special health risk for infants, young children, and people with severely compromised immune systems.

[6] Although there is no collective MCLG for this contaminant group, there are individual MC for some of the individual contaminants:

- Trihalomethanes: bromodichloromethane (zero); bromoform (zero); dibromochloromethane (0.06 mg/L). Chloroform is regulated with this group but ha MCLG.
- Haloacetic acids: dichloroacetic acid (zero); trichloroacetic acid (0.3 mg/L). Monochloroacetic acid, bromoacetic acid, and dibromoacetic acid are regulated wi group but have no MCLGs.

[7] MCLGs were not established before the 1986 Amendments to the Safe Drinking Water . Therefore, there is no MCLG for this contaminant.

[8] Lead and copper are regulated by a Treatment Technique that requires systems to cont corrosiveness of their water. If more than 10% of tap water samples exceed the action lev water systems must take additional steps. For copper, the action level is 1.3 mg/L, and fo is 0.015 mg/L.

[9] Each water system must certify, in writing, to the state (using third-party or manufacture certification) that when acrylamide and epichlorohydrin are used in drinking water system combination (or product) of dose and monomer level does not exceed the levels specifiec follows:

- Acrylamide = 0.05% dosed at 1 mg/L (or equivalent)
- Epichlorohydrin = 0.01% dosed at 20 mg/L (or equivalent)

National Secondary Drinking Water Regulations

National Secondary Drinking Water Regulations (NSDWRs or secondary standards) are r enforceable guidelines regulating contaminants that may cause cosmetic effects (such as or tooth discoloration) or aesthetic effects (such as taste, odor, or color) in drinking water: recommends secondary standards to water systems but does not require systems to corr However, states may choose to adopt them as enforceable standards.

- For more information, read Secondary Drinking Water Regulations: Guidance for Nuisance Chemicals.

Contaminant	Secondary Standard
Aluminum	0.05 to 0.2 mg/L
Chloride	250 mg/L
Color	15 (color units)
Copper	1.0 mg/L
Corrosivity	noncorrosive
Fluoride	2.0 mg/L
Foaming Agents	0.5 mg/L
Iron	0.3 mg/L
Manganese	0.05 mg/L
Odor	3 threshold odor number
pH	6.5-8.5
Silver	0.10 mg/L
Sulfate	250 mg/L
Total Dissolved Solids	500 mg/L
Zinc	5 mg/L

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